PLANT PATHOLOGY

A RECORD OF CURRENT WORK ON PLANT DISEASES AND PESTS

Published Quarterly for the
Ministry of Agriculture, Fisheries and Food
Plant Pathology Laboratory
Harpenden, Herts

VOLUME 5, No. 1

March 1956

LONDON: HER MAJESTY'S STATIONERY OFFICE

York House, Kingsway, London, W.C.2; 423 Oxford Street, London, W.1
13A Castle Street, Edinburgh, 2; 39 King Street, Manchester, 2;
2 Edmund Street, Birmingham, 3; Tower Lane, Bristol, 1;
109 St. Mary Street, Cardiff; 80 Chichester Street,
Belfast

CONTENTS

	Page
Spraying Practice against Apple Scab on Bramley's Seedling in the Wisbech Area, in 1953 and 1954. *I. F. Storey and June V. Ives*	1
The Control of Wireworm in Potatoes by Aldrin	9
Cocksfoot Moth Investigations. *D. W. Empson*	12
Slow Wilt of Carnations caused by a Species of Erwinia. *R. A. Lelliott* ..	19
Cereal Root Eelworm : A Farm Survey. *L. E. W. Stone*	24
A Colorimetric Method for measuring Dosage Distribution in Potato Spraying. *P. Hebblethwaite*	26
Observations on a Race of Stem Eelworm attacking Lucerne. *E. B. Brown and J. B. Goodey*	28
Survival of *Phytophthora infestans* in Potato Stem Lesions. *Angela M. Clayson and N. F. Robertson*	30
A New Bacterial Disease of Dahlias caused by *Pseudomonas marginalis*. *Marjorie R. M. Clark and A. M. Paton*	32
The Weather of England and Wales	37
New or Uncommon Plant Diseases	37
Black Rust on Wheat in England and Wales in 1955	38

Plant Pathology is sold direct by Her Majesty's Stationery Office at the addresses given on the title-page or through any bookseller. Price of single copies 4*s.* 0*d.* net (4*s.* 1½*d.* by post). Subscription rate 16*s.* 6*d.* for four issues, including postage. Subscriptions, notifications of changes of subscribers' addresses and inquiries about delivery of copies should be addressed to H.M. Stationery Office, P.O. Box No. 569, London, S.E.1.

Unless otherwise stated, all material in this publication is Crown Copyright, and may not be reproduced without the permission of the Controller of H.M. Stationery Office.

The Ministry accepts no responsibility for the commercial advertisements included in this publication.

In the interests of factual reporting, occasional reference in this Journal to trade names and proprietary products may be inevitable. No endorsement of named products is intended, nor is any criticism implied of similar products which are not mentioned.

Manuscripts for consideration and all correspondence on plant pathology matters should be addressed to the Editor, *Plant Pathology*, Plant Pathology Laboratory, Milton Road, Harpenden, Herts. Other editorial correspondence should be addressed to The Production Editor, *Plant Pathology*, Whitehall Place, London, S.W.1 (Tel. Trafalgar 7711).

PRINTED IN GREAT BRITAIN

SPRAYING PRACTICE AGAINST APPLE SCAB ON BRAMLEY'S SEEDLING IN THE WISBECH AREA, IN 1953 AND 1954

by I. F. STOREY AND JUNE V. IVES

National Agricultural Advisory Service, Cambridge

In parallel with the spore trapping investigations carried out at Wisbech St. Mary during 1953 and 1954 (Hirst, Storey, Ward and Wilcox, 1955), a survey was made of forty orchards in 1953 and ninety-nine in 1954 to review the fungicidal treatments used and their relative effectiveness in this district where control of Apple Scab *Venturia inaequalis* (Cooke) Wint. on Bramley's Seedling has proved to be very difficult. The majority of these orchards were within a 10-mile radius of the orchard where spore trapping was done, and as conditions are relatively uniform throughout this district, there is no reason why meteorological observations and spore counts made at Wisbech St. Mary should not be applicable to the whole of the area. The age and size of the trees is fairly similar throughout this district, the majority being 30–50 years old on a seedling crab rootstock and producing trees up to 30 feet in height.

Full details of the spray programme and dates of application were obtained from the grower for each orchard and the amount of scab present on the fruit was assessed by the visual method of Croxall, Gwynne and Jenkins (1952), in the month before picking. A minimum of sixty assessments was made for each orchard, 5 runs of branches about 6 feet in length on at least 12 trees being recorded. The figure for the severity of scab in the orchard was obtained by taking the mean of all the units, and this is referred to as the scab assessment.

SEVERITY OF SCAB IN 1953 AND 1954

The results of the survey of scab on the fruit, irrespective of the spray programme, are shown in Table 1. Both seasons were very favourable for the development of scab and in both years unsprayed trees in the area produced

TABLE 1

INCIDENCE OF SCAB ON APPLE FRUIT IN BRAMLEY'S SEEDLING ORCHARDS. WISBECH DISTRICT, 1953 AND 1954

Scab Assessment *per cent*	1953 No. of Orchards	1953 Percentage	1954 No. of Orchards	1954 Percentage
0·001– 0·009 ..	2	5	4	4
0·01 – 0·09 ..	4	10	44	44
0·1 – 0·9 ..	12	30	30	30
1·0 – 9·9 ..	12	30	15	15
10·0 –100 ..	10	25	6	6
	40		99	

little fruit of market quality. If anything, scab was worse on the unsprayed trees in 1954 than in 1953. However, the proportion of orchards showing severe scab infection was much greater in 1953 than in 1954. This difference may be attributed to the heavy, early ascospore discharge in 1953 and to the more widespread use of the newer fungicides to control the disease in 1954. In

1953, over one-half of the orchards surveyed had a scab assessment which indicated that at least one-half of the fruit on the tree was scabbed. In consequence, its market value was much reduced.

COMPARISON OF FUNGICIDAL TREATMENTS

A comparison of the degree of scab control given by various materials, either used alone or in combination, was possible. The following fungicides were used in the orchards surveyed :

Lime sulphur was generally applied at 3–5 per cent at bud-burst, at 2–3 per cent later, and at 1 per cent for the post-blossom application.

Bordeaux mixture with excess lime was freshly prepared from copper sulphate and hydrated lime, generally with a 4 : 9 : 100 mixture for the earlier applications, dropping to 3 : 9 : 100 for the later.

Mercurial preparations. A variety of materials were in use, including phenyl mercury acetate, chloride, nitrate and oxine, and a soluble organo-sulphonate. More than half the mercury spray applications were of phenyl mercury nitrate. The water in the Wisbech area often has a high chloride content, and as phenyl mercury nitrate is readily converted to the less soluble chloride (Weed and Ecker, 1931), it is possible that a freshly prepared solution of phenyl mercury chloride is, in effect, the active fungicidal material. On Bramley's Seedling the phenyl mercury nitrate preparation was generally used for all applications at 2 lb per 100 gal, giving a mercury concentration of 0·0031 per cent. Some of the other materials were used at a slightly lower mercury concentration.

Captan (*N*-trichloromethylthio-*cyclo*hex-4-ene-1:2-dicarboxyimide) was used as a wettable powder at the rate of 2–2½ lb per 100 gal.

A few growers used ziram and glyoxalidine (Crag 341), but these materials were used in too few orchards for inclusion in the analysis.

Five main types of spray programme could be distinguished, and the degree of scab control given by these during the two seasons is given in Table 2. In the rest of the orchards the spray programme was too varied for inclusion in the table.

TABLE 2

INCIDENCE OF SCAB ON BRAMLEY'S SEEDLING FRUIT IN RELATION TO THE TYPE OF SPRAY PROGRAMME USED. WISBECH DISTRICT, 1953 AND 1954

	1953		1954	
	No. of Orchards	Mean Scab Assessment *per cent*	No. of Orchards	Mean Scab Assessment *per cent*
Lime sulphur only	8	15·5	3	4·2
Lime sulphur and mercury ..	13	4·5	25	1·9
Bordeaux and mercury ..	3	0·1	13	0·3
Mercury only	6	0·2	35	0·8
Captan only	—	—	3	0·01

The poor control of scab given by an all-lime sulphur programme is clearly indicated, and this was most marked in 1953 when scab infection became established on the foliage at a very early stage of development. In both years a better control was obtained where Bordeaux mixture and the mercurial preparations were used. The trend in favour of an all-mercury programme is very marked when it is realized that there were very few orchards in this area

in 1952 having a complete mercury programme. This trend has continued, so that in 1955 it was the exception to find a Bramley's Seedling orchard that had anything other than mercurial preparations for scab control. There is nothing to suggest that a programme starting with Bordeaux mixture and finishing with mercury is any better than an all-mercury one, provided the sprays are well timed.

The degree of control obtained with captan was extremely good and all the evidence we have on its effect on other varieties in the Eastern Province confirms that this material is a most effective scab fungicide. However, observations in 1954 on plots sprayed the two previous years with a variety of fungicides have been given by Ward (1955), and these indicated that there was a greater risk of increasing Apple Mildew, *Podosphaera leucotricha* (Ell. and Everh.) Salm., by the use of captan and glyoxalidine than with lime sulphur or mercury. The control of mildew given by phenyl mercury nitrate was considerable and the difference between this and lime sulphur was not very great. Workers in New Zealand have obtained control of mildew by mercurial sprays (Cunningham, 1952) and observations made in the Wisbech area in orchards sprayed for three years with these materials showed no build-up of infection comparable with that given by the captan or glyoxalidine sprays. The lack of mildew control given by these two materials agrees with observations made at the East Malling and Long Ashton Research Stations (Moore, 1955 ; Byrde and Fielding, 1953).

It was impossible to get any reliable information from the survey as to the relative effectiveness, among themselves, of the several different mercurial preparations for scab control, but a trial to compare three of these materials was carried out at Upwell in Norfolk in 1954 by Mr. D. Mellard and Mr. B. D. Meeke of the N.A.A.S. Sprays were applied to single plots on April 7 and 20, May 4 and 19, and June 1, 15 and 28. The scab assessments made on the fruit just before the picking were as follows :

	Rate of Application	*Scab per cent*
Phenyl mercury nitrate	2 lb per 100 gal (0·0031% Hg)	0·010
Phenyl mercury acetate	1¼ lb per 100 gal (0·0031% Hg)	0·015
Soluble organo-mercury sulphonate	2 pt. per 100 gal (0·0018% Hg)	0·028

The degree of control given by all treatments was very good, especially in view of the very favourable season for the development of scab. The sulphonate spray gave slightly poorer control, but with this material the concentration of mercury in the spray is two-thirds that of the other materials used. Reference to the data of the ascospore release in the Wisbech area in 1954 (Hirst *et al.*, 1955) shows that the spray applications were well timed in relation to the main periods of ascospore release, and the timing of the spray applications in relation to infection periods is shown in Fig. 2 (2nd orchard).

EFFECT OF TIME OF FIRST SPRAYING

The 1953 season was characterized by a very early release of ascospores at the time of bud-burst during the last week in March, and the first infections were to be found sporing on the leaves in late April. Most growers intended to rely on lime sulphur for scab control, and Fig. 1 (*left*) shows the time of the first lime sulphur spray in relation to the amount of scab on the fruit just before picking. Similarly, in Fig. 1 (*right*) the effect of the time of the first mercurial spray on fruit scab is shown. In many orchards these sprays were preceded by Bordeaux or lime sulphur sprays, but when once mercurial sprays had been applied their use was continued for the rest of the season.

(3914) A**

The data presented in Fig. 1 show that few orchards were protected by a fungicide at the end of March, and it was nearly three weeks later before the first spray application was given to some orchards in the area. There is no indication that the orchards having the earliest lime sulphur applications had less scab than those where this was delayed for some time. The mercurial sprays, however, behaved quite differently, and the cleanest orchards were those which had received the earliest applications. The longer this was delayed the greater the amount of scab developing on the fruit. Mercurial sprays preceded by Bordeaux mixture gave better control of scab than those preceded by lime sulphur. The behaviour of these sprays reflects their differing modes of action, and it is suggested that the value of the mercurial preparations in this season was based on their ability to eliminate infections already established on the tree, whilst lime sulphur and Bordeaux mixture were unable to do so to anything like the same extent.

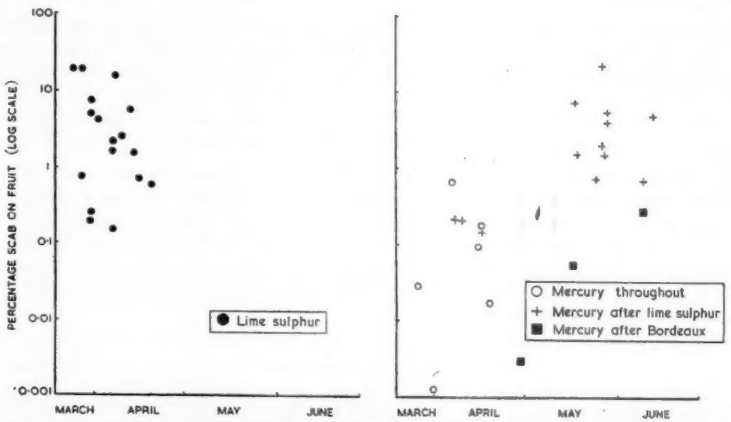


Fig. 1. Effect of time of first application of (*left*) lime sulphur and (*right*) mercury sprays on amount of scab on fruit. Wisbech, 1953.

In 1954, the time of the first fungicide application had no effect on the scab infection which developed. Many growers had sprayed at least twice before the first infections took place during the period May 1–5. By this time most orchards had received their first mercurial spray, but the effect of continuing after May 1 with either lime sulphur or Bordeaux mixture showed the same effect as in 1953 in that the later these were replaced by mercurial sprays the worse the control of scab.

EFFECT OF NUMBER OF SPRAY APPLICATIONS

There was no indication that the total number of sprays applied to an orchard had very much effect on the degree of scab control ; in fact, some of the worst orchards for scab had the largest number of sprays. The most marked effect was produced by the number of sprays during the effective phase of ascospore activity. We defined this phase as starting with the liberation of ascospores that caused the first infections and ending ten days after the time when the last ascospores were trapped. In 1953, this phase was from March 25 to about May 15, and the cleanest orchards had at least four sprayings during this time.

In 1954 it was from May 1 to June 11 : the cleanest orchard had five sprays and the poorest only two.

The data relating to mercurial sprays in 1954 are given in Table 3. It will be seen that there is a direct relationship between the number of sprays during the critical phase, and the scab assessment. A regression analysis on this data showed that the effect was significant at the 1 per cent level.

TABLE 3

EFFECT OF MERCURIAL SPRAYS ON THE CONTROL OF SCAB ON BRAMLEY'S SEEDLING. WISBECH DISTRICT, 1954

Scab Assessment on Fruit	No. of Orchards	Average No. of Sprays	Average No. of Sprays May 1–June 11	Average Interval between Infection Period and Spray (days)	
per cent				*before*	*after*
0·001– 0·009 ..	1	12·0	5·0	6·5	4·0
0·01 – 0·09 ..	25	8·0	3·2	7·3	6·9
0·1 – 0·9 ..	15	8·6	3·0	7·5	7·5
1·0 – 9·9 ..	4	7·3	2·3	7·1	9·0
10·0 –100·0 ..	2	8·5	2·0	7·1	10·8

The value of sprays applied during the effective phase of ascospore activity combines with the evidence from spore trapping to confirm that the ascospores are responsible for the early outbreaks of scab. This phase will vary from season to season, but such evidence as we have from the Wisbech area suggests that it may begin any time from bud-burst onwards. Failure to get adequate control of scab during this phase makes it very difficult, or impossible, to achieve it by later spray applications.

APPLICATION OF MERCURY IN RELATION TO INFECTION PERIODS

The observations at Wisbech add to the evidence that the mercurial sprays have the power to kill infections already established on the tree, and that the critical time for their application is during the spring and early summer, when the ascospores are being liberated from the old leaves on the ground. Recent work in America (Sproston, 1949) and Holland (Besemer *et al.*, 1955) has suggested that the most effective results can be obtained with the mercurial sprays when they are applied just after the spores have begun to germinate and for some days after penetration has occurred. According to Mills and LaPlante (1951), infection takes place when the leaves have been wet for varying lengths of time after rain, depending on the average temperature. Rain is required to wet the old leaves and liberate the ascospores, and to provide a film of water for the germination of these spores.

With this in mind, and having no direct observations on leaf wetness, an attempt was made to delimit the periods in 1954 when ascospore infection took place. From observations at Wisbech St. Mary we knew that the first infections resulted from the weather prevailing during the early days of May, and subsequent infection periods were taken as those when the relative humidity in the orchard remained above 70 per cent for 24 hours or more following rain. It was considered that high humidity following rain would enable the water film to persist long enough to allow the fungus to penetrate into the tissues.

During the time of ascospore liberation four main infection periods could be distinguished. They started on May 1, 15, 20 and 28 and coincided with the four heavy ascospore discharges during May. (Hirst *et al.*, 1955.) We know

that infections resulted from the period at the beginning of May, as scab was first found in the orchards on May 24. It is of interest that the last two periods were slightly earlier than those recorded at Utrecht in Holland in 1954, where the number of hours the leaves remained wet was used as a basis for recognition. The weather system which resulted in the occurrence of these periods in the Wisbech area gave similar conditions in Holland but at a slightly later date.

The times of application of mercury sprays in relation to the four infection periods were considered by taking the time interval between the spray application both before and after the first day of each infection period. The average times elapsing between spraying and the infection periods for groups of orchards having different amounts of scab are given in Table 3.

There was little difference between the good and bad orchards in the length of time *before* infection periods when the sprays were applied. On the other hand, there was a striking relationship between the degree of scab control and the timing of the spray application *after* such periods. The cleanest orchards were those in which the interval between infection and spraying was the shortest. We assumed for the purpose of this analysis that infection took place on the first day of each infection period, but if it did not occur until later, then the interval between infection and spraying would be even shorter than that given here.

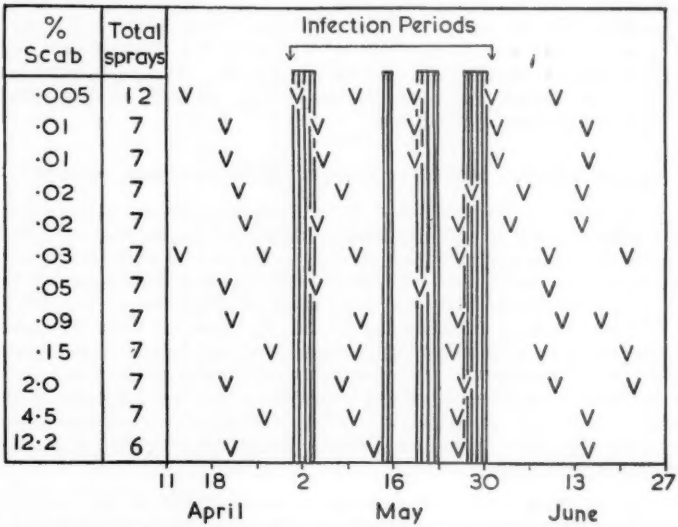


Fig. 2. Application of mercurial sprays in relation to infection periods in twelve orchards during the time of ascospore liberation. Bramley's Seedling, Wisbech, 1954. V = date of spraying.

A demonstration of the importance of well-timed applications of mercury in relation to the first four infection periods after growth started in 1954 is given in Fig. 2. Orchards were selected which had received only seven sprays during the growing season. All had mercury sprays after mid-April and five out of ten had nothing but phenyl mercury nitrate. The cleanest, and also one of the most severely scabbed orchards, where this material was used throughout,

are included for comparison. This group of orchards was chosen because the number of applications was below the average for the district. In the cleaner orchards of this group one would expect the timing of the sprays to be as near the ideal as possible.

As a general rule, the onset of an infection period found the cleaner orchards less well protected than those where scab control was poor ; on the other hand, the cleaner orchards were those to which sprays were applied soon after the occurrence of an infection period. There was also some evidence that a spray applied just preceding the start of conditions suitable for infection may have had a protective effect. Such a spray was probably given on May 19, but those given on May 25–27 do not appear to have been beneficial in this respect. An inch of rain fell on May 28 and may have removed much of the fungicide before it had had time to act on the germinating spores, whereas the rainfall on the days following May 19 was slight (*see* Hirst *et al.*, 1955). The upper part of the diagram indicates the way in which curative sprays gave their best results. In contrast, the picture for a successful *protective* spray programme would show that the sprays had been applied shortly before the infection periods. It is the curative method of applying mercurial fungicides which has led to the most efficient control of scab in the Wisbech area.

TIME OF SPRAY APPLICATION IN RELATION TO A SINGLE INFECTION PERIOD

Further evidence of the value of a well-timed mercury spray in relation to an infection period was obtained during the 1955 season. Following a prolonged dry spell a copious release of ascospores occurred on April 27, and this was followed by conditions suitable for infection. Scab was first seen on the leaves on May 13. At the end of the month a number of orchards within two miles of the spore trap were examined and the proportion of spurs bearing scabbed leaves was estimated by examining at least 300 spurs taken at random throughout each orchard. Phenyl mercury nitrate fungicide at the rate of 2 lb per 100 gal (0·0031 per cent Hg) had been applied in almost all these orchards.

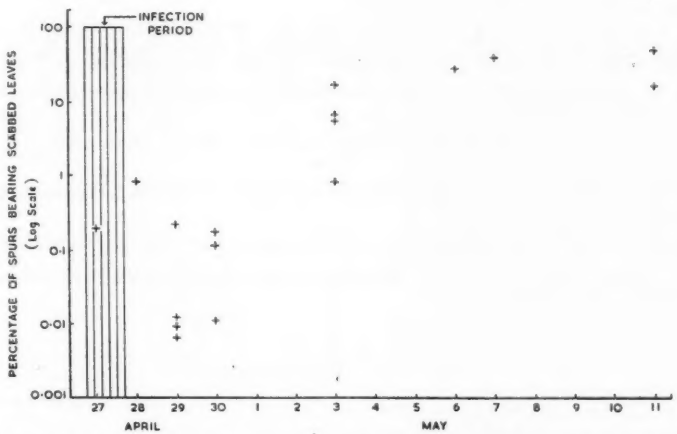


Fig. 3. Scab infection of foliage on May 31 in relation to date of first spraying with mercury after infection period. Wisbech, 1955.

The proportion of spurs bearing infected leaves in relation to the date of spray application is given in Fig. 3. A good degree of control was obtained where the spray was applied up to 4 days after infection. From 4–6 days the result was variable and after 7 days a spray had very little effect. These results show clearly the effectiveness of a well-timed application of mercurial spray and also how narrow are the limits between complete efficiency and uselessness.

The value of a curative spray of this type is that effective applications can usually be timed far more accurately than is possible where one is relying mainly on protective effects. It is for this reason that we feel the need for further work in this country on a method suitable for use by the fruit-grower to delimit the periods when infection is taking place. Furthermore, there is a need for a more precise classification of the scab fungicides on their ability to give curative and protective effects.

During the period under review, there has been an almost complete change-over from lime sulphur to mercurial preparations for the control of scab on Bramley's Seedling in the Wisbech area. The best results have been obtained where the spray programmes were such as to make full use of the curative properties of these newer materials.

Thanks are due to our colleagues H. J. Eaton, R. W. Kemp, B. D. Meeke, D. Mellard, Miss E. D. Usherwood, W. C. Ward and H. J. Wilcox for their help; to all the growers who so readily gave information on their spray programmes and provided facilities for work in their orchards; and to the Statistics Department at Rothamsted Experimental Station for analysis of some of the data.

REFERENCES

BESEMER, A. F. H., DIJKSTERHUIS, H. P., KEIJER, E. J., ROOSJE, G. S. and VLASFELD, W. P. N. (1955). Het Schurftonderzoek in 1953 en 1954. *Meded. Dir. Tuinb.*, **18**, 297–323.

BYRDE, R. J. W. and FIELDING, A. H. (1953). Spraying Experiments against Apple and Pear Scab at Long Ashton, 1952. *Rep. agric. hort. Res. Sta. Bristol*, 1952, 125–31.

CROXALL, H. E., GWYNNE, D. C. and JENKINS, J. E. E. (1952). The Rapid Assessment of Apple Scab on Fruit. *Plant Pathology*, **1**, 89–92.

CUNNINGHAM, G. H. (1952). Report of Plant Disease Division. *26th Ann. Rep. Dep. sci. industr. Res. N.Z.*, 1952, 58–62.

HIRST, J. M., STOREY, I. F., WARD, W. C. and WILCOX, H. J. (1955). The Origin of Apple Scab Epidemics in the Wisbech Area in 1953 and 1954. *Plant Pathology*, **4**, 91–6.

MILLS, L. D. and LAPLANTE, A. A. (1951). Diseases and Insects in the Orchard. *Cornell Ext. Bull.* No. 711, 21–7.

MOORE, M. H. (1955). The Search for Better Fungicides. *Rep. E. Malling Res. Sta.*, 1954, 152–4.

SPROSTON, T. (1949). Vermont Apple Scab and Control, 1947–1948. *Bull. Vt agric. Exp. Sta.*, No. 550.

WARD, W. C. (1955). Wisbech Solves Problems of Apple Scab. *The Grower*, **43**, 683–7.

WEED, L. A. and ECKER, E. E. (1931). The Utility of Phenyl Mercury Nitrate as a Disinfectant. *J. infect. Dis.*, **49**, 440–9.

THE CONTROL OF WIREWORM IN POTATOES BY ALDRIN

Contribution from the Conference of Entomologists, National Agricultural Advisory Service, compiled by W. J. Bevan, N.A.A.S., Leeds, and J. W. Bryden, N.A.A.S., Reading

During the last ten years, BHC has been effectively and extensively used for the control of wireworm in potatoes in the form of a 2½–3½ per cent dust broadcast and worked into the soil before planting at a rate of 1½ cwt per acre. Some root crops, and particularly potatoes, are susceptible to BHC taint, not only on land treated immediately before planting but, not infrequently, where treatment is applied some years before potatoes are set. In 1953 aldrin became generally available in the United Kingdom. It was claimed that this material was not phytotoxic and did not taint vegetable and root crops grown in treated soil.

The entomologists in the National Agricultural Advisory Service carried out trials with it in 1953 and 1954. The design and scope of individual experiments varied. Three methods of application were tried : a 1¼ or 1½ per cent dust at rates of 1·05 to 3·36 lb of active material, worked in, or applied to ridges before planting ; a pre-planting spray of miscible oil containing 30 per cent aldrin at a rate of 3·06 lb of active material in 40 gallons of water per acre ; and a combined insecticide and fertilizer applying quantities varying from 0·84 to 3·00 lb of insecticide per acre.

Results were assessed by various methods. In general, random samples of tubers were examined for wireworm damage at lifting and the percentage of tubers damaged, or the total number of wireworm borings per 100 tubers, recorded. Lack of a uniform method limits comparison of the results, and the percentage of damaged tubers has been selected as the most convenient criterion. In seven experiments tubers were graded according to the number of wireworm borings and, although the classification varied in some degree between trials, all included the class " five or more holes per tuber ", which is a useful index of unsaleability.

A total of six replicated and four observation trials were carried out in the Eastern, South Eastern, South Western, West Midland, Yorkshire and Lancashire, and Northern Provinces. Wireworm density was assessed by the wet extraction method. The results are summarized in Table 1 in terms of the mean percentage of tubers showing signs of wireworm damage at lifting.

TABLE 1

PERCENTAGE OF TUBERS WITH WIREWORM DAMAGE IN RELATION TO DOSAGE OF ALDRIN

Number of Trials	Wireworm Density per acre	Controls	0·8–1·9 lb per acre	2·0–2·5 lb per acre	2·6–3·4 lb per acre
1	1,650,000	97	—	67	—
1	950,000	74	48	24	37
2	425,000	54	7	4	2
2	275,000	87	18	30*	8
1	225,000	73	24	4	2
3	125,000	34	16*	4	4

* At one site only.

The lower application rates clearly have not reduced wireworm damage to a satisfactory level, although reduction over the controls is marked. In one trial

(Northern Province) an initial wireworm density of 420,000 per acre caused holing in 39 per cent of the tubers on the control plots and in 3–4 per cent of those from plots treated with 1·4 and 2·1 lb aldrin respectively (two replications). In another trial (West Midland Province) an initial wireworm density of about 300,000 per acre caused holing in 86 per cent of the control plot tubers, in 28 per cent of those on the plots which received 1·68 lb, and in 30 per cent of those on the plots treated with 2·5 lb of aldrin before planting. There are clear differences in the efficiency of a given dose of insecticide. In this respect it is of interest that about 74 per cent of the control plot tubers were holed in an Eastern Province trial in which the wireworm population was assessed at 950,000 per acre, and in a trial in Yorkshire in which only about 225,000 wireworms per acre were detected. In the first case 3·36 lb of aldrin reduced damage to 37 per cent, whilst in the second it was reduced to 2 per cent by this dosage. It is pertinent to note here that even the highest rate of dosage used in any of the trials did not reduce damage to a satisfactory level when wireworm density was high.

The results from five of the experiments have been tabulated with regard to severity of damage and expressed as the percentage of tubers with more than five wireworm borings (Table 2). This grading is indicative of unsaleability as ware, even in a season when potatoes are scarce, as it would be practically impossible to sell a crop with an appreciable proportion of tubers so holed at lifting, and storage would almost certainly result in further deterioration.

TABLE 2

PERCENTAGE OF TUBERS WITH MORE THAN FIVE WIREWORM BORINGS IN RELATION TO DOSAGE OF ALDRIN

N.A.A.S. Province	Wireworm Density per acre	Controls	0·8–1·7 lb per acre	2·1–2·5 lb per acre	3·0–3·6 lb per acre
W. Midland	1,650,000	96	47	5	—
Yorks and Lancs ..	425,000	16	0	0	0
W. Midland	300,000	48	2	0	0
Yorks and Lancs ..	225,000	10	3	0	0
S. Eastern	150,000	25	2	0	0

With the exception of the West Midland trial on a field with a density of over 1½ million wireworms per acre, the insecticide considerably reduced the proportions of seriously damaged tubers even at the lowest dosages, and in the severe West Midland test 2·5 lb of aldrin applied before planting clearly had a marked effect on damage. In another trial in the Eastern Province on a field with a density of nearly one million wireworms per acre, 2·5 lb aldrin per acre reduced the percentage of damaged tubers from 74 to 24, the treated tubers having roughly half the number of borings occurring in those from the control plots. It seems evident that, where high wireworm populations are found, aldrin treatment is unlikely to result in a completely satisfactory control of damage in potatoes, and a less susceptible crop should be planted whenever possible.

Limited data are available on the use of aldrinated fertilizer and on aldrin as a low-volume spray. However, the results indicate that when 2–3 lb per acre are applied in either of these ways the degree of wireworm control and crop protection is similar to that obtained by dust treatments before planting. The cost of wireworm control with aldrinated fertilizer is approximately the same as with miscible oil formulations, and at present is rather less than the cost of a low percentage dust. A disadvantage of the use of combined fertilizer is

that the rate of fertilizer application is predetermined by the dosage necessary to give satisfactory pest control.

Data are available from seven sites on the effect of aldrin on wireworm density, as assessed from soil samples taken before treatment and again after lifting. At four sites in South Wales applications of 2·0–3·0 lb aldrin per acre reduced wireworm density from 700,000 to 50,000, 400,000 to 50,000, 750,000 to 50,000 and 600,000 to 50,000, per acre respectively, whilst the population remained the same on an untreated control. All samples were hand sorted. In three other experiments in which, unfortunately, different extraction methods were used for the pre- and post-cropping samples, the indications are that aldrin treatment reduced density to between one-seventh and one-tenth of its level on the control plots at lifting.

At five trial sites data were collected on the incidence of slug damage to tubers. The results are set out in Table 3, expressed as the percentage of tubers with signs of slug attack in relation to insecticide dosage.

TABLE 3

PERCENTAGE OF TUBERS WITH SLUG DAMAGE IN RELATION TO DOSAGE OF ALDRIN

N.A.A.S. Province	Number of Replicates	Controls	0·8–1·7 lb per acre	2·0–2·8 lb per acre	3·0–3·6 lb per acre
Northern	2	46	11	4	—
W. Midland	1	27	8	—	—
Yorks and Lancs ..	4	22	—	10	9
S. Eastern	4	21	5	2	4
Eastern*	4	22	8	3	5

* Eastern Province results expressed as numbers of slug holes per sample of 100 tubers.

When aldrin is used for wireworm control there appears to be a reduction in slug damage. Slugs may act as secondary feeders and it is not known whether this reduction is due to direct action, or indirectly through a reduction in wireworm holes. In a trial carried out in the Eastern Province in 1954 aldrin was applied in a field with a very low wireworm population in an attempt to assess any direct effect on slugs. The results showed that there was no reduction in damage by *Agriolimax reticulatus* (Mull.) and *Arion hortensis* (Fer.) on the treated plots, compared with the controls.

In seven of the experiments, samples of tubers from each plot were submitted to tasting panels. In no case was any off flavour or taint detected in the treated tubers. Some tasters recorded an unpleasant flavour in tubers from both treated and control plots in one of the trials.

The work indicates that about 2 lb aldrin per acre applied to the soil before planting potatoes gives a reasonable reduction in wireworm damage at population levels below about 500,000 per acre. Below this level of density about 4 per cent of tubers may show symptoms of wireworm attack, and occasionally the treatment is not effective to this extent. Associated with the reduction in numbers of damaged tubers there is a reduction in the amount of damage on those which have been attacked. No evidence of taint was obtained from the trials, and further work on the effect of aldrin treatments on slug attack is clearly desirable. These conclusions are similar to those from trials carried out in 1954 in Northern Ireland and reported in the *Monthly Agricultural Report*, Government of Northern Ireland, January 1955.

We would like to thank those farmers who allowed experiments to be carried out on their potato crops ; also those members of the National Agricultural Advisory Service who carried out the field investigations.

COCKSFOOT MOTH INVESTIGATIONS

by D. W. EMPSON

National Agricultural Advisory Service, Wolverhampton

The Tineid moth, *Glyphipterix cramerella*, was described first by Fabricius (1777) from English specimens, but between 1839 and 1946, when the full synonymy was published by Fletcher (1946), the specific name *fischeriella* Zeller was applied to it. Its economic importance was first noted by Stainton (1870). Chopra (1925) published the results of two years' work on the Cocksfoot moth but had not discovered the site of hibernation of the larvae. An increasing interest in the home production of herbage seeds has prompted this publication of the results of some work done on the moth between 1944 and 1947.

In 1944, the seed from a 7-acre cocksfoot stand near Stockbridge in Hampshire was completely lost through Cocksfoot moth damage. Further investigation revealed that every stand in the county was infested to some extent, and the total loss in 1944, in Hampshire, was estimated to be between 6 and 7 tons of seed. In 1945, partly because of successful attempts at control, the loss was reduced to between 3 and 4 tons of cocksfoot seed. Since 1945 less damage has been observed, although the species has remained abundant on wild cocksfoot.

MORPHOLOGY

The stages have been described in Chopra (*loc. cit.*) so only brief notes are given here. The egg is oval with a smooth shell. It is pearly-white in colour, becoming greenish and darker with maturity. Its average dimensions (16 eggs) are 0·344 mm × 0·158 mm. The larva is a very pale greenish-white on hatching, becoming yellowish-green with maturity. The head capsule and dorsal plates are pale brown on hatching and become dark brown to almost black with maturity. The testes of mature male larvae are clearly visible as paired red to red-brown spots lying in the fifth and sixth abdominal segments. Mature female larvae have, on average, slightly but significantly wider head capsules than males. The larvae are of typical Tineid form with the prothoracic plate divided by an uneven mid-dorsal suture. They have three characters of taxonomic importance: a row of twelve purplish spots ventrally forming a median longitudinal series, about equally spaced from the prothorax to the seventh abdominal segment inclusive; the crochets of each proleg are reduced to a single pair of hooks, one hook being placed on each of the anterior and posterior edges of the apical disc; and each thoracic leg is terminated by a single claw between a pair of transparent processes—each process being about one and a half times as long as the claw, about as wide as the claw, and rounded at the end. Dimensions on hatching are 1·0 mm × 0·15 mm and, when mature, 5·5–6·0 mm × 0·8–0·9 mm.

The pupa has its fourth to seventh abdominal segments movable, although the antennae and legs are not at all free. The antennae extend to the third, wings to the seventh, and legs almost to the eighth, abdominal segments. Female pupae are slightly more rounded posteriorly than males. Average dimensions are 3·25–3·50 mm × 0·85–0·90 mm.

The adult has dark brown forewings which are slightly metallic with a black apical spot. A typical specimen has five evenly-spaced, silvery streaks along its costa, two along the dorsum, and one arising from the middle of the tornus (Plate I, 1). The hindwings are dark grey but not metallic, with cilia evenly grey. The sexes are similar, and have a wing spread of 7–9 mm.

LIFE HISTORY

Eggs are laid in cocksfoot heads in June, before the grass has flowered. Each is inserted by the female inside a floret between the glume and the palea and above the developing stamens. The eggs hatch after ten to fifteen days, according to the weather. The young larva first eats its eggshell and then the developing stamens. It works its way downwards and eventually eats the lodicules, thus preventing the opening of the floret. The first moult then takes place. The second moult occurs after one or two florets or " seeds " have been eaten, and the third and last after a total of four or five seeds has been destroyed. During its life each larva damages about ten seeds of normal size. This observation was checked by dividing the number of damaged seeds in a head with the number of overwintering larvae in the related stem. The histogram (Fig. 1), derived from 228 such counts from a number of localities, shows a peak at nine and ten seeds eaten per larva. Cocksfoot grass (*Dactylis glomerata* Linn.) is the only known host plant.

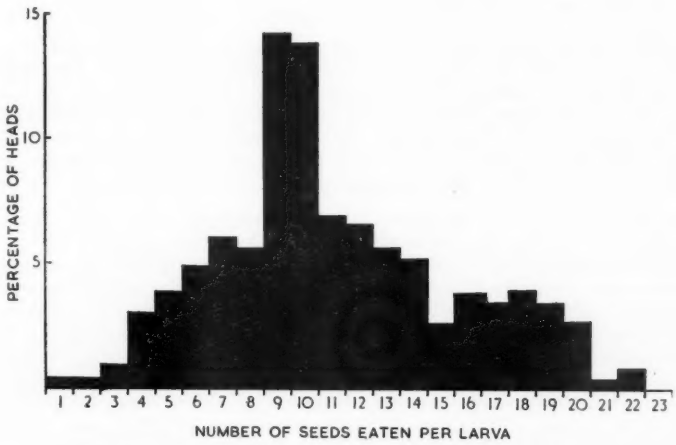


Fig. 1. Frequency diagram for number of seeds eaten per larva.

After the first week of larval life, when the contents of two or three florets have been eaten, feeding is confined to the developing kernels. A floret damaged by a Cocksfoot moth larva is not entirely eaten. The larva makes a hole in either the glume or the palea and eats the kernel. It then passes on to the next seed, leaving the remainder of the husk entire (Plate I, 3). The larva may make only one hole in each attacked seed or, particularly when older, two. The number of holes in 100 seeds rises with the severity of attack, since each seed may be entered by more than one larva :

Percentage Infestation	Number of Seeds Examined	Average No. of Holes per 100 Seeds
0–20	4,068	168·4
20–40	3,551	170·4
40–60	7,980	173·6
60–80	6,711	184·5

(3914) A***2

The larval stage lasts three or four weeks, according to the weather. When the larva is fully fed it leaves the flower-head and travels down the stem. It crawls beneath a leaf sheath, usually the second from the top of the stem, and comes to rest about two or three inches below the ligule. It then bores a hole in the hollow stem, about 1 mm in diameter, and enters the stem (Plate I, 2). Larvae leaving the head later may use the same hole, and the likelihood of this increases with the severity of the attack. Inside the stem the larva may move up or down for a variable distance, but it cannot pass through a node. After coming finally to rest, the larva spins a cocoon over itself or, in a very narrow stem, closes the stem above and below with pads of silk. A perfect cocoon is 6–7 mm long and about 1½ mm wide. At this stage, the larval length is reduced to 4 mm or less, and it lies with its head at the centre of the cocoon.

From December onwards a conical exit hole is made in the stem, the debris being packed in the unoccupied half of the cocoon. By the time the larva is ready to pupate, the hole is such that the stem at this point is reduced to a thin cuticle. The numbers of the sexes of overwintering larvae are about equal (sex ratio of 2,000 larvae = 0·543).

The first pupae were found on March 10 in 1945 and April 6 in 1946. The first adults appeared on May 10 in 1945 and May 7 in 1946. The length of time in the pupal stage is therefore very variable, but in the majority of cases it was found to be about three or four weeks. The pupa becomes active shortly before emergence. The final position of the pupal case indicates that the cuticle covering the emergence hole is broken by the pupa. Males emerge, on the average, four or five days before the females.

Cocksfoot moth adults have been observed from May 7 to June 22 and are most numerous during the last week of May and the first week of June. They are diurnal and fly rapidly and frequently in sunshine. When the moths are at rest the wings are moved or shuffled alternately in a manner characteristic of the genus *Glyphipterix*. The rate of this movement is greatest in sunshine and ceases immediately the insect begins to feed. They feed at most of the flowers appearing during the flight period, the only notable exception being Red Clover (*Trifolium pratense* Linn.). They were recorded at flowers of twenty-six plant species of thirteen families. Feeding at flowers is not an essential preliminary to laying viable eggs. This may be either because sugar can be obtained from secretions of aphids in the cocksfoot heads or because it is not necessary.

Mating has been observed within three days of emergence and takes place in the evening. There is a preliminary mating flight from about 4.30 p.m. G.M.T. until about 6.30 p.m. G.M.T., during which the males fly above the females with a characteristic buzzing flight. Between 5.30 p.m. and 6.30 p.m. the pairs start copulation, which lasts for about three hours. Oviposition may be observed at any time between 9 a.m. and 4 p.m. The normal time taken for the laying of an egg is about 2½ minutes. The ovipositor is inserted between the glume and palea, an egg being laid only if there is ample room above the stamens.

In the spring, adults may be found on cocksfoot heads and at flowers. Size, colour and the alternate wing movements should provide adequate identification. Adults are unlikely to be flying unless the sun is shining.

During the summer, cocksfoot heads may be examined for holes in the sides of the florets and the presence of small green larvae. The seed-head normally shows no external sign of attack. As the seeds are ripening the larvae leave

the heads and may be found by sweeping or merely walking through the crop. For year-to-year comparisons examinations should be made at the same distance (say, 30 yards) from each headland.

During autumn and winter, the stubble may be examined for entrance holes in the stems, and confirmation obtained by splitting open the stems. An attacked crop gives a high proportion of waste during threshing. If the blowings are examined the holes in the seeds may be found.

ECOLOGY

According to Meyrick (1928), the Cocksfoot moth is found throughout Europe, in Asia Minor and North Africa. It does not occur in New Zealand, although the genus *Glyphipterix* is well represented there. A survey in 1945 showed that the species was present in all the 36 English counties from which samples were obtained. Chopra (*loc. cit.*) recorded its occurrence in all but three of the Welsh counties and also from Edinburgh, Perth, Dundee, Aberdeen and eastern Ireland. It therefore seems probable that the moth is present in the British Isles wherever its food-plant grows.

The distribution in wild cocksfoot was investigated during the winter of 1944–45. The number of larvae in ten stems was counted for each of 100 sampling points within 50 miles of Reading. Details of the degrees of sunshine, dryness (in winter) and shelter were noted for each sampling point and expressed as " high ", " medium " or " low ". The frequency of cocksfoot at the site was also noted. The mean count for each level of these factors, with the numbers of samples in each group (in brackets), were as follows :

Factor	High	Medium	Low
Sunshine	41 (45)	45 (41)	33 (14)
Dryness	46 (56)	30 (29)	46 (15)
Shelter	39 (45)	48 (44)	25 (11)
Frequency of cocksfoot	86 (25)	35 (54)	5 (21)

Little correlation with the first three factors appears, although very shaded and sheltered situations gave low counts. The counts are, however, directly related to the abundance of the host grass at the sampling site.

Population estimates were made on the various plots of National Institute of Agricultural Botany trials of cocksfoot strains. From six of such trials an index of attack was obtained for each strain. This figure was negatively correlated with the ash and fibre content of samples of harvested seed. The differences were too small to be of practical consequence, but it may be noted that the valuable extreme pasture types tended to be more heavily attacked than hay or " commercial " strains.

During 1946, a survey of 66 seed stands of cultivated cocksfoot was made with the assistance of Advisory Entomologists and the County Agricultural Executive Committee staffs. Each observer gave details of one or more crops and sent a sample of 100 stems from each crop or stubble for the counting of hibernating larvae. The counts from stubbles were corrected for the average length of straw, the correction having been determined from samples of whole stems. Details from sufficient stands were available for : harvest year ; method of harvesting in previous year (binder or combine harvester), and whether stubble was burned (combine only) ; and frequency of older cocksfoot (wild and cultivated) near the stand. The results are given in the table overleaf. The numbers of stands in each group are given in brackets.

ANALYSIS OF POPULATIONS IN COCKSFOOT SEED CROPS

(Mean numbers of larvae per 100 stems)

Harvest Year	Previous Harvest by	Previous Stubble Treatment	Frequency of Older Cocksfoot High	Medium	Low
1st	—	—	69 (2)	23 (8)	8 (22)
2nd	Combine	Burned	—	24 (1)	10 (1)
	Binder		—	53 (8)	19 (6)
	Combine	Not burned	366 (1)	124 (2)	—
3rd	Combine	Burned	—	—	26 (1)
	Binder		392 (2)	164 (3)	67 (3)
	Combine	Not burned	518 (1)	—	143 (1)
4th	Binder		—	1,069 (1	62 (3)

CONTROL BY BIOLOGICAL AND CULTURAL MEANS

Six species of Hymenopterous parasites were bred from Cocksfoot moth larvae. Of these species, four overwinter in the stubble and are destroyed by burning. Some moth larvae are attacked during the winter by small Carabid larvae (*Dromius* sp.). There may also be a high mortality of larvae in the late autumn, the cause of which is unknown. In wild cocksfoot the overwintering survival rate in 1945 and 1946 was found to average about 50 per cent. In cultivated cocksfoot it was found to be about 60 per cent at the headland, rising to over 80 per cent in the middle of the stand. It was concluded that although natural control reduces the number of moths available for the primary infection of a stand, it provides very little check to a rapid increase in the stand itself.

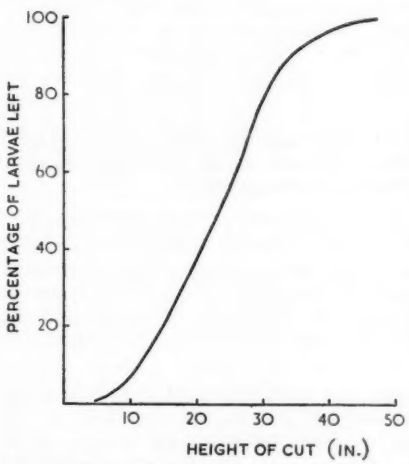


Fig. 2. Percentage of larvae left in stubble in relation to height of cut. Average stem length of crop 40 inches. A rather higher proportion of larvae is left in stubbles from shorter crops.

The height of cut at harvest was found to be an important factor affecting the degree of infestation in the following year. In a normal crop with straw length of 40 inches the larvae tend to group themselves inside the hollow stems at about 20 inches above the ground. It was found that a binder cutting at between 8 and 10 inches leaves about five per cent of the larval population still in the stubble, whereas a combine harvester cutting at about 22 inches leaves about 40 per cent behind (Fig. 2). As a tentative estimate, it appears that where 10 per cent or less of the larval population remains in the stubble, Cocksfoot moth damage is unlikely to increase, provided re-infestation is slight.

Neither cattle nor sheep were found to eat the cut flowering stems but there was considerable treading by cattle. In a number of stands which had been grazed, the trodden stems contained larvae, of which the majority were alive. Adults were numerous in the following spring. It is

concluded that grazing of the stubble in the autumn cannot be considered as a measure for the control of the Cocksfoot moth.

It has been shown that the Cocksfoot moth population depends to a large extent on the abundance of nearby and older cocksfoot plants. From this it follows that the destruction of old flowering stems of wild cocksfoot before the emergence of adults in April will be beneficial. It was found that pasture and hay crops containing cocksfoot were only of importance if left uncut for a season; a state which is frequently found in the corners of hay fields. Due regard to the practicability of wild cocksfoot destruction should be paid when siting new stands. Many crops have suffered heavy loss, even in the first year, through infection from adjacent common land.

Advantage was taken of a trial of nitrogenous manuring of cocksfoot in Hampshire in 1944 to determine the effect, if any, of such treatment on Cocksfoot moth attack. Heavy nitrogen dressings advanced the date of flowering by about three days and gave an increased yield. The actual loss per acre from moth damage was slightly greater on the " high nitrogen " plots.

Many growers of cocksfoot seed make a practice of burning stubbles after harvest. They claim that the plant benefits from better ventilation, provided the burning is done before flower-buds are formed in October. The discovery that Cocksfoot moth larvae hibernated in the stems indicated that a general adoption of stubble burning might give adequate control of the pest. It was found that the stems, although charred, survived the fire. A large number of such stems was collected and the contents compared with those from equal numbers of stems from unburned stubbles. Twenty-seven living and 2,363 dead larvae were found in the burnt stems, compared with 3,900 living and 462 dead in the unburnt stems. Burning therefore reduced survival from 89 per cent to just over 1 per cent.

In order to discover the effect on infestations in the following year, five stands were sampled in the autumn of 1944, immediately before burning, and again in the autumn of 1945. Similar sampling was carried out on five unburned stands. All harvesting was by combine harvester and the counts were of larvae (including those dead and parasitized) in 100 stems of 22-inches length taken at 30 yards from the headland. The means and ranges of the counts of the five crops in each case were as follows :

	1944	1945
Burned	195 (24–288)	27 (8–51)
Not burned	114 (21–292)	712 (134–1,569)

It thus appears that stubble burning gives an adequate degree of control. Unfortunately, it is not possible to burn stubbles every year, but if no opportunities are missed after harvest it could probably be done in three years out of four. Unless the straw is very wet a fire started with paraffin will continue to burn, provided there has been little fresh growth after harvest. Damp stubbles should be burned with the wind, dry ones against it. Stubble burning must be carried out before October. This does not apply to wild cocksfoot ; very satisfactory clearance may be achieved by burning during dry weather in winter and early spring.

CHEMICAL CONTROL

Live larvae are only rarely found in seed samples and the treatment advocated by Chopra (*loc. cit.*) is not necessary. An attempt was made to kill larvae in the stems by spraying with white oil emulsion after harvest. Applications of

up to 200 gallons per acre of 1 per cent white oil emulsion had no effect and did not appear to have penetrated the cocoons.

Various trials of spring dusting were carried out on 1/16-acre plots. Four per cent nicotine dust and 2·5 per cent DDT dust were used in 1945, and 5 per cent BHC dust in 1945. All the treatments gave an immediate reduction of the numbers of adults on the dusted plots but made no significant differences to the subsequent larval populations. It is now thought that this failure may have been caused by the plots being too small in relation to the mobility of the adults. The 5 per cent BHC dust caused a significant ($P = 0{\cdot}05$) reduction in the rate of larval parasitism from 3·6 to 1·2 per cent.

In view of the success of stubble burning no further trials were arranged. Where burning has been impossible, however, and an attack is feared, a dust or spray with one of these insecticides over the whole field might prove to give an economic degree of control.

The recommended control measures may therefore be grouped as follows :

1. Siting of new stands away from wild and cultivated cocksfoot.
   Destruction of sources of infestation.
2. Low cutting at harvest.
   Stubble burning.

It is sufficient to adopt only one of the control measures in each group.

CONCLUSIONS

The results of this work indicated that all cocksfoot seed crops grown in this country are likely to be exposed to attack by Cocksfoot moth. The degree of infestation increases with the age of the stand. Moth populations are higher where combine harvesters have been used, unless the stubbles have been burned ; and the degree of infestation is also dependent on the amount of older cocksfoot in the locality.

In general, the work has shown that effective control may be obtained by destroying sources of infection or siting new stands away from wild or cultivated cocksfoot, coupled with low cutting at harvest or stubble burning.

These investigations were carried out under the direction of Mr. W. E. H. Hodson, and formed part of a thesis approved for the degree of Ph.D. in the University of Reading. The surveys were made with the assistance of members of the Conference of Advisory Entomologists and officers of the County Agricultural Executive Committees. The photographs were taken by Mr. A. Sherval.

REFERENCES

CHOPRA, R. L. (1925). On the Structure, Life-History, Economic Importance and Distribution of the Cocksfoot Moth, *Glyphipterix fischeriella* Zell. *Ann. appl. Biol.*, **12**, 359–97.

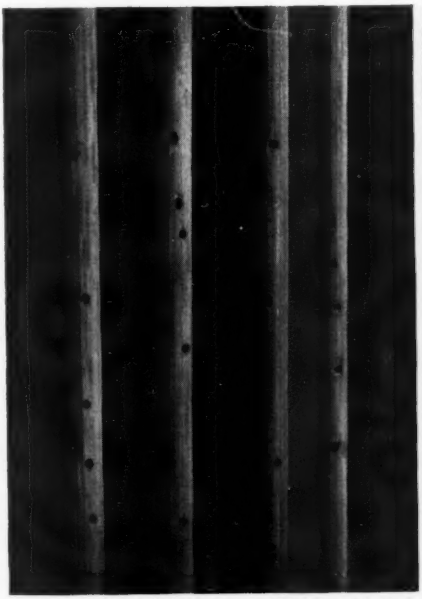
FABRICIUS (1777). *Genera Insectorum.* 296–7.

FLETCHER, T. B. (1946). Names of Microlepidoptera. *Ent. Rec.*, **58**, 127.

MEYRICK, E. (1928). *A Revised Handbook of British Lepidoptera.* Watkins and Doncaster, London, 709.

STAINTON, H. T. (1870). *Natural History of the Tineina.* J. van Voorst, London, **11**, 266–76.

1. Adult moth, *Glyphipterix fischeriella* Zeller. × 20

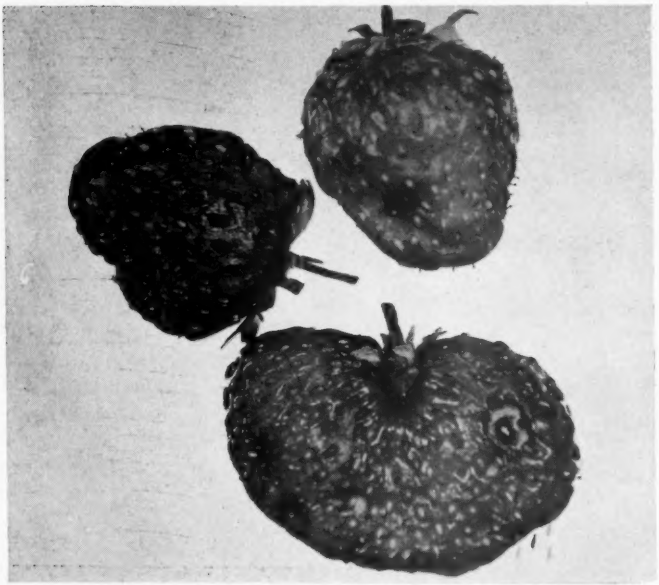


2. Stems of cocksfoot grass showing entrance holes of larvae. × 2½

3. Cocksfoot moth damage to seeds.
Top row : damaged.
Bottom row : undamaged. × 5

PLATE I

BLACK SEED OF STRAWBERRY (see *p. 37*)



1. Fruit showing brown and shrivelled depressions caused by *Mycosphaerella fragariae.*

CEREAL ROOT EELWORM (see *pp. 24–5*)

2. Yellowed Cereal Root eelworm patch in field of oats at Rushall, Wiltshire, 1955.

PLATE II

A NEW BACTERIAL DISEASE OF DAHLIAS (*see pp. 32–5*)

1. Mature plant with several shoots affected by *Pseudomonas marginalis*.
2. Cuttings showing basal rot.
3. Cutting showing interveinal blackening of leaf tissues.

COLORIMETRIC MEASUREMENT OF SPRAY DOSAGE DISTRIBUTION
(*see pp. 26–8*)

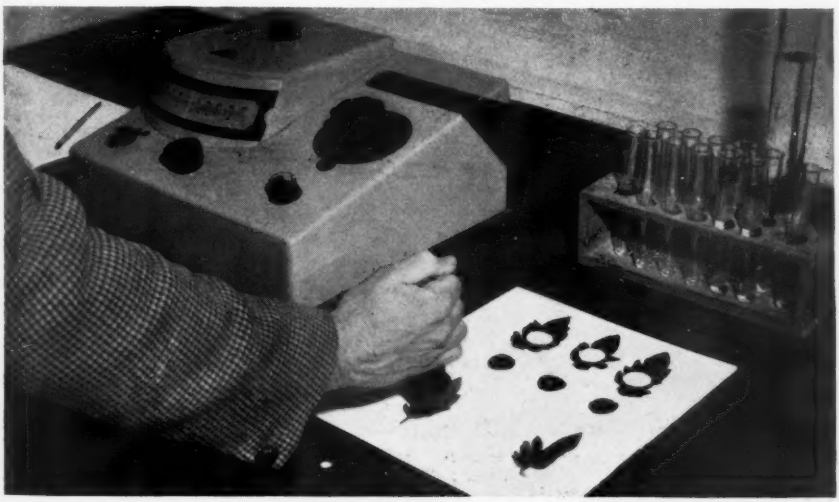
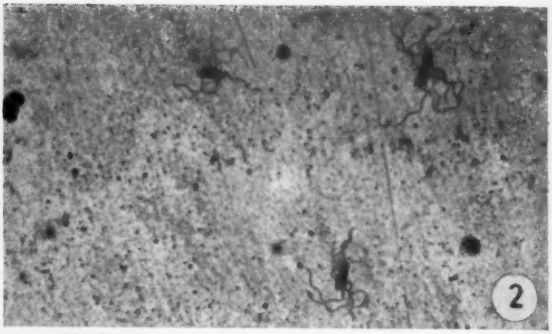
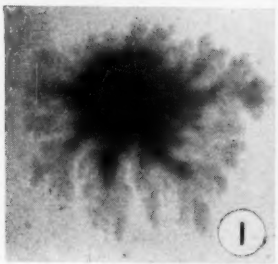
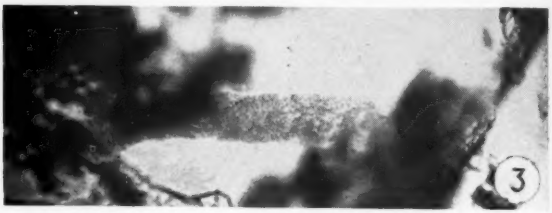


Photo: N.I.A.E.

4. Cutting leaf discs with a wad punch. Each disc is washed with a measured amount of water in a test-tube, and the concentration of dye (from an addition to the spray fluid) is measured with an absorptiometer.







1. Colonies on potato-dextrose agar. *Above* : "feathery"; oblique light. × 5.
   Below : "coralloid"; transmitted light. × 6
2. Flagellae. Gray's method. × 1600
3. Rod of gelatinous matter containing bacteria. Teased preparation. × 190
4. Part of inoculated plant showing wilting and shrivelling leaves. × $\frac{2}{3}$
5. Inoculated 6 month-old plant, showing severe stunting. × $\frac{2}{3}$

PLATE IV

SLOW WILT OF CARNATIONS CAUSED BY A SPECIES OF ERWINIA

by R. A. LELLIOTT

Plant Pathology Laboratory, Harpenden, Herts

In September 1954, wilting carnations from a nursery in Essex were sent to me for examination, following a field diagnosis of Bacterial Wilt, *Pseudomonas caryophylli*, made by Mr. E. Hellmers of Copenhagen. At that time Mr. Hellmers also diagnosed this disease on a nursery in Hertfordshire, but unfortunately the stock was destroyed by the grower before specimens were obtained. Later in 1954 wilted specimens were sent in from Sussex by Dr. H. H. Glasscock, and, early in 1955, I received further material from nurseries in Hertfordshire and Essex, collected by Mr. J. E. E. Jenkins. None of the plants yielded *Ps. caryophylli*, but a different bacterium was consistently isolated from the vascular systems of the specimens. Isolates made by Mr. Jenkins from affected plants on the original nursery in Essex, and later from other nurseries both in Essex and in Hertfordshire, agreed culturally with mine, and attempts made by him to isolate *Fusarium* spp. or *Verticillium cinerescens* were unsuccessful.

The symptoms of the disease suggested that it could appropriately be named " Slow Wilt ". A similar disease has been reported from Holland (Bakker and Scholten, 1955) which, although ascribed to *Ps. caryophylli*, may prove to be Slow Wilt.

DISTRIBUTION, INCIDENCE AND ORIGIN OF INFECTION

In the spring and early summer of 1955, in collaboration with Mr. Jenkins, a search for Slow Wilt was made in most of the carnation nurseries in Hertfordshire, and in four of these its presence was confirmed. It was also found in two of a number of nurseries visited in Essex. In August and September of the same year a more widespread survey was made, and the disease was discovered in two nurseries in Bedfordshire, two in Sussex and one in Hampshire. It was not found in Middlesex, Buckinghamshire, Berkshire or Kent. In all, a search had been made in forty-one nurseries by the autumn of 1955, and the disease had been found in eleven of them. It appeared to be firmly established in many varieties in two of the nurseries—one in Essex and one in Sussex. On the other nine, the infection, though often severe, was confined to only a few stocks.

The total number of infected stocks found in 1955 was twenty-four, of which eleven were known to have been imported from Holland, or to be the progeny of stocks from there. A further six were probably of similar origin, and two had become infected from Dutch stock. Two others had been imported from Denmark in 1955. With one exception, all the infected stocks were of varieties raised in the U.S.A., Holland or Denmark. In recent years growers have relied largely on Holland and Denmark for new varieties, and particularly for obtaining the American Sim varieties. One stock of a variety raised in England was affected, possibly from contact with imported stock. It would appear that Slow Wilt had been introduced into this country since 1950, probably in the first place, and certainly subsequently, from Holland.

It is interesting to note that one of the two very slightly affected Danish stocks had been tested as cuttings for Bacterial Wilt by the method suggested by Hellmers (1955), while the other was taken from a tested mother stock.

The only case of Bacterial Wilt found was in a sample of six plants taken from a small wilting stock on a nursery in Hertfordshire. *Ps. caryophylli* was isolated from one plant and the Slow Wilt bacterium from four of the remaining five. This stock had been imported in 1954 from Holland.

SYMPTOMS

Just after the beds are planted up, infected plants can often be picked out by their unthrifty appearance, lighter colour, rather staring habit, and flaccidity and loss of bloom of the leaves. A slow progressive wilt develops (Plate IV, 4) and plants become grey-green. These symptoms usually develop over many months before the plant is finally killed ; in one stock seen in 1955 many plants were still just alive nearly a year after infection had first been noted. This very slow decline is probably a common feature of the disease, as it has been observed in three other affected stocks and also in experimentally infected plants. Although plants grown from naturally or artificially infected cuttings often show the first external symptoms when about three months old, symptom development can be delayed for many months. Progressive wilting does not always occur and plants may be stunted and make little growth (Plate IV, 5). A root rot accompanies the aerial symptoms but basal stem rotting has not been seen. The stems of infected plants are often extensively cracked, but this is an unreliable diagnostic character because cracking is not uncommon, though usually less severe, on healthy plants.

The inner wood of the infected stem is usually brown at the base. The discoloration tails off into streaks which become lighter, dry and frayed towards the top of the stem. Sometimes, and particularly in young plants, the wood is discoloured only in streaks at the stem base. Where the stem is cracked, the underlying wood is often disorganized, leaving a dry necrotic pocket.

ANATOMY OF DISEASED TISSUES

Sections and teased preparations from affected plants showed the bacteria mainly in the vessels, with little or no necrosis of surrounding tissue or dissolution of the vessels themselves. Heavily infected groups of vessels were often traced to the tops of the stems and laterals. Teased preparations showed the bacteria to be densely packed in the vessels, devoid of Brownian movement, and embedded in gelatinous matter, which was often extruded from the broken ends of the vessels. Occasionally, and especially in young xylem, the bacteria lay with their long axes parallel to the sides of the vessels, and those in the extruded matter were similarly orientated. Teased preparations also showed very light brown rods of gelatinous matter, about 50μ wide and up to 500μ long, containing masses of bacteria which appeared to be the contents of infected vessels from which the walls had been broken and pulled off (Plate IV, 3).

METHOD OF ISOLATION

The bacterium was readily isolated, from some 120 plants, by the following method. Each stem was broken open and a small part of one of the brown strands in the wood was teased out with needle knives into a drop of sterile water on a flamed slide and covered with a flamed coverslip. One slide was used to test tissue from three plants. If the bacterial masses, described above, could be seen under a microscope, the slide was placed on a damp filter paper in a petri dish and left at room temperature for at least 6 hours or overnight. The coverslip was then taken off and a loopful of the water was streaked on a

dry potato-dextrose agar plate. After 4–5 days incubation at 27°C the characteristic colonies of the bacterium developed. It was found essential to ensure that the plates were quite dry and that the gelatinous masses were allowed to disperse before streaking.

INOCULATION TESTS

Six Crawley Sim and six White Sim cuttings were inoculated by dipping their roots in a water suspension of a pure culture of the bacterium. Symptoms appeared in some of the plants after two months and were present in eleven of them after three months. One of the thirteen controls wilted, but *Verticillium cinerescens* was isolated from it by Mr. Jenkins. Twelve unrooted William Sim cuttings were dipped in a similar suspension but, in these, symptoms developed more slowly, appearing in some after three months and being present in only nine after six months. None of the twelve control cuttings showed symptoms. The Slow Wilt bacterium was recovered from thirteen of the fourteen plants from which re-isolation was attempted.

To compare the symptoms of Slow Wilt and Bacterial Wilt each pathogen was inoculated into twelve William Sim rooted cuttings, and these, together with twelve control plants, were kept at a continuous soil temperature of about 90°F. Bacterial Wilt killed the plants in 2–3 weeks, but the plants infected with Slow Wilt had not shown symptoms after 6 weeks. In a similar comparison at the summer greenhouse temperatures of 1955, the development of Slow Wilt was more protracted than that of Bacterial Wilt, although the first symptoms began to appear at about the same time. A severe sticky basal rot was present only in plants affected with Bacterial Wilt.

CHARACTERS OF THE BACTERIUM

The methods used to characterize the bacterium were essentially those described in the S.A.B. *Manual of Methods* (S.A.B., 1954). Except where stated, the incubation temperature was 27°C. Utilization and fermentation of sole carbon sources were tested in 1 per cent solutions of carbohydrates, 0·15 per cent solutions of organic acid salts, and 5 per cent solution of ethyl alcohol in an inorganic basal medium (Ayres, Rupp and Johnson, 1919), for 28 days. All organic substances were sterilized by filtration and added aseptically to the autoclaved basal medium. The production of acid or alkali was tested by adding brom-cresol purple or brom-thymol blue respectively to some tubes after the bacterium had made good growth and to the rest of the tubes after 28 days. All tests were duplicated.

The description which follows is based on the study of six isolates from different nurseries and on one re-isolate.

The pathogen is a gram-negative, non-sporing straight rod with rounded ends, and occurs singly or in pairs. Freshly isolated, 24-hour heart-peptone agar cultures consist of short rods 0·8–3·2 × 0·5–0·8μ (mean 1·8 × 0·6μ) with a few longer, filamentous cells. These long cells (reaching 50μ) are more frequent in older isolates, particularly in sub-cultures more than a few days old, and cannot be separated by four successive streakings or pourings of single colonies. Cells are motile with 3–14, but more usually 8–11, peritrichous flagella (Plate IV, 2).

Good growth is made on heart infusion-peptone agar and colonies are circular, low convex, translucent, smooth, shining and whitish with entire edges. Growth is less rapid on potato-dextrose agar but produces an unusual type of colony. Young colonies are either circular, convex, smooth and entire, or sculptured with irregular margins ; these two colony types depend on the

dryness of the agar surface and both can be reproduced at will by streaking on plates dried for different lengths of time. After 4–5 days both colonies are similar and resemble a fried egg with a pinkish, round, raised centre and lobed periphery, which later becomes feathery, or almost coralloid (Plate IV, 1). Colonies on Difco Endo agar are pink and no change occurs in the colour of the medium.

On both heart and potato-dextrose agars, streaking on freshly poured plates produces a spreading growth which covers the plate in 2–3 days. Growth in heart infusion-peptone broth is good and a ring of surface growth, which sinks after about 48 hours, is formed. A viscid precipitate forms which later becomes coarsely granular. No growth is made on 5 per cent NaCl-nutrient broth, but moderately good growth is made in Fermi's solution. In litmus milk, litmus is reduced in the bottom half of the tube after 6 days and all the litmus is reduced in 14 days. A soft curd begins to develop after 5 days, and this becomes firm after 19 days with clearing at the top of the tube.

Liquefaction of gelatin stabs starts in 24 hours, is saccate in 48 hours and complete in 8 days. Slight amounts of H_2S are produced in tryptone broth; tests for indole production are positive by Kovac's method but negative by Gnezda's method, indicating that α-methyl indole is formed rather than indole itself. Nitrite, but no nitrogen, is produced from nitrate. Starch is not hydrolized. The bacterium is citrate +, M.R.−, and V.P.+ ; it is urease negative in Difco urea broth. It is a facultative anaerobe.

Xylose, d-glucose, arabinose, mannose, galactose, sucrose, raffinose, mannitol and salicin are utilized as sole carbon sources with the production of acid and small volumes of gas ; rhamnose, glycerol and ethyl alcohol with acid alone, and maltose with slight acid (only detected with brom-thymol blue). Lactose, sorbitol, erythritol and sodium hippurate are utilized with no change in reaction, and sodium salts of malic, succinic, citric, tartaric and acetic acids and ammonium lactate with the production of alkali. Sodium formate is not utilized. Utilization of most of the carbon sources occurs in 1–4 days and acid and gas production in 2–6 days, but utilization of sodium tartrate and ethyl alcohol is delayed for 10 days and lactose and erythritol for 18–20 days.

Gas production by all isolates tends to be erratic in that occasionally one or two tubes fail to produce gas. Three of the isolates failed to produce gas from arabinose ; production by the other three was very small and was delayed for 12 days.

Potato slices are completely rotted in 48 hours at 22°C.

The sensitivity of four isolates to a range of antibiotics was tested by the filter disc-plate method. Plates were seeded with equal volumes of water suspensions of bacteria adjusted to give equal percentage light transmissions on

MEAN OF INHIBITION ZONE DIAMETERS FOR FOUR ISOLATES (mm)

	10	*30*	*60**
Chloromycetin ..	23·5	27·0	30·0
Aureomycin ..	21·0	24·5	26·0
Terramycin ..	19·0	23·0	28·0
	0·5	*1*	*10†*
Penicillin	0·0	0·0	0·0
	5	*10*	*30**
Polymyxin B ..	8·5	10·0	12·5

	2	*10*	*20†*
Bacitracin ..	0·0	0·0	0·0
	1	*10*	*100**
Streptomycin ..	0·0	13·0	—
Dihydro-streptomycin	0·0	13·0	18·0

* Concentration in ug. per ml.
† Concentration in units per ml.

a Unicam spectrophotometer. The diameters of the inhibition zones with the four isolates did not vary by more than two mm for antibiotics giving a diffuse zone edge and one mm for those giving a clear cut edge. The table shows that the bacterium can be considered very sensitive to aureomycin, chloromycetin, and terramycin, moderately sensitive to polymyxin B, dihydrostreptomycin and streptomycin, and resistant to bacitracin and penicillin.

IDENTITY OF THE BACTERIUM

The bacterium is obviously closely related to the coliform group, and although some of its morphological and cultural characters indicate affinities with *Proteus* Hauser, it is excluded from this genus by its absence of urease production. Comparison with cultures of *P. vulgaris* and *P. mirabilis* has also shown that the stained flagellae of the bacterium are generally shorter, stouter and have a longer pitch, and that the multi-flagellated and the giant cells of swarming *Proteus* cultures are absent.

The bacterium has many characters in common with a group of gas-forming species enjoying a doubtful position in the genus *Erwinia* Winslow. Within this group it most resembles *E. chrysanthemi* (Burkholder, McFadden and Dimock, 1953). Delayed utilization of lactose, growth in Fermi's solution, and lack of growth in 5 per cent NaCl are common to both organisms and distinguish them from *E. carotovora*. Despite differences between the two organisms, the carnation pathogen may be regarded as a strain of *E. chrysanthemi* until its exact taxonomic status is determined.

The position of the Dutch carnation wilt pathogen which Bakker and Scholten (1955) described is difficult to determine. They diagnosed it as a variety of *Ps. caryophylli*, in spite of its gas-forming abilities and rapid gelatin liquefaction. Gas production is not a character of *Ps. caryophylli* and in the genus *Pseudomonas* itself it is restricted to a small group of saprophytes and weak animal pathogens which Kluyver and van Niel (1936) consider should be transferred to a new genus *Aeromonas*. In view of the origin of many of the Slow Wilt outbreaks in this country and the close resemblance of the Slow Wilt bacterium, apart from flagella type, to the description of the Dutch organism, it is possible that Bakker and Scholten were mistaken in ascribing polar flagella to their organism and that the two bacteria are the same.

I am indebted to Mr. W. Buddin, Dr. H. H. Glasscock, Mr. E. R. Keithley, Mr. W. H. Nourish and Mr. A. E. Waterfield for help in surveying nurseries, and particularly to Mr. J. E. E. Jenkins for sending plants and isolates from infected nurseries in his area.

REFERENCES

AYRES, S. H., RUPP, P. and JOHNSON, W. T. (1919). A Study of the Alkali-forming Bacteria in Milk. *Bull. U.S. Dep. Agric.*, No. 782, 1–39.

BAKKER, M. and SCHOLTEN, G. (1955). Een bacterie-verwelkingsziekte in Amerikaanse anjers. *Tijdschr. PlZiekt.*, **61**, 7–10.

BURKHOLDER, W. H., MCFADDEN, L. A. and DIMOCK, A. W. (1953). A Bacterial Blight of Chrysanthemums. *Phytopathology*, **43**, 522–6.

HELLMERS, E. (1955). Bacterial Wilt of Carnations. *Gdnrs' Chron.*, **137**, 194.

KLUYVER, A. J. and VAN NIEL, C. B. (1936). Prospects for a Natural Classification of Bacteria. *Zbl. Bakt.*, (*Abt. 2*), **94**, 369–403.

S.A.B. (1954). *Manual of Methods for Pure Culture Study of Bacteria.* Society of American Bacteriologists, Geneva, New York.

CEREAL ROOT EELWORM: A FARM SURVEY

by L. E. W. STONE

National Agricultural Advisory Service, Bristol

In the summer of 1954, cysts of *Heterodera major* (O. Schmidt) Franklin were found on oat roots at a farm in Wiltshire by Mr. L. N. Staniland. Since the farm was primarily concerned with the production of cereals, it was fully surveyed for eelworm (Plate II, 2). Twenty-nine fields, comprising about 1,200 acres, were sampled in the autumn of 1954 by three teams of two workers, so that the results would be available before the spring sowing of 1955.

Fields to be sampled were divided into 12–15 acre units ; 50 samples were then taken from each unit, from which 200 grammes of soil were floated off in the laboratory. Four lots of 50 grammes of air-dried soil were examined per sampling unit.* The technique described by Fenwick and Franklin (1942) was modified and found to work satisfactorily. After soaking in water for 3–4 days, each cyst was opened by means of the glass squasher described by Fenwick. The liberated larvae were fixed by water at 75°C and measured straight away, using a micrometer eyepiece. Five larvae per cyst were measured. If their mean length was $> 550\mu$, the cyst was assumed to be *H. major*. Records were kept of cysts with more and less than 50 eggs. Cyst populations were too low to make egg counts worth while.

Larval identification was simple in most cases, though on occasion the five larvae varied considerably in length—a typical example being 475, 520, 545, 550, 570μ. These cases were investigated and it was found that team A had identified 2 per cent of cysts as doubtful out of 205 examined, team B identified 25 per cent as doubtful out of 117 examined, and team C identified 64 per cent as doubtful out of 25 examined. It is clear that observer differences are important in this work. Two points are worthy of note here. First, it may be thought that, owing to an insufficient waiting period between liberation and measurement, the larvae were not allowed to swell to the accepted length. If this were so, one would expect the mean length of all larvae regarded as *H. major* to be less than 582μ, the mean quoted by Fenwick and Franklin (1951). In fact, the mean length of 164 sets of five larvae on which complete records are available was 583μ. This factor would not therefore seem important. Secondly, it is possible that injured larvae were measured, particularly by teams B and C, since the larvae were not checked by staining (Fenwick and Franklin, 1942). This may have happened inadvertently, though each worker was asked to avoid measuring injured larvae.

SURVEY RESULTS

Cereal Root eelworm was found in 16 of the 29 fields sampled—that is, in 55 per cent. The mean infestation (0·022 cysts per gramme, or one cyst per 43·5 grammes of soil) was, however, lower than might be expected where cereals are grown so frequently. The soil on the farm is a medium loam overlying chalk. Five fields where the soil was heavier yielded no *H. major* cysts.

In general, the correlation between crop performance and *H. major* populations was good. The mean cyst counts (per 200 grammes of soil) from fields

* It has since been learned that a more complete recovery of *H. major* cysts is obtained by refloating the dried sediment from the initial flotation. This recovery is, however, likely to be related to the original one and is therefore unlikely to alter the relative infestivity of fields as determined by the method described.

classified by the farm manager on crop performance since 1949, as good, fair, etc., were as follows :

Reputation of Field	Number of Fields	*H. major* Population
Good	8	0·1
Fair	16	1·9
Poor	4	7·2
Failure (Oats, 1954)	1	29·4

Over the period 1949–54, comprising 174 crop-years on the 29 fields, 122 were occupied by cereals and 26 by leys down for one, two or three years. The classification of the fields according to their ley history, with corresponding mean cyst counts (per 200 grammes of soil) of *H. major* and other lemon-shaped cysts, was as follows :

Ley History	Number of Fields	*H. major*	Others
No ley	12	3·4	0·9
1-year ley	11	1·3	1·4
2-year ley	3	0·6	2·5
3-year ley	3	0·9	4·5

The figures for the other cysts may indicate a build-up of *H. schachtii* var. *trifolii*, Goffart, but other species were probably present as well.

The populations of the sixteen fields where *H. major* was found fell into three distinct categories : eight had low populations, four produced intermediate counts, and the remaining four contained high populations. For each group of fields, data from each sampling unit were used to analyse the variation within and between fields. The transformation $\sqrt{x + 0{\cdot}5}$ was used, where x is the number of cysts per sampling unit. The results were as follows :

Mean Cyst Count per 200 grammes of Soil	No. of Fields	Mean Squares for $\sqrt{x + 0{\cdot}5}$ Cysts per Sampling Unit	
		Between Fields (d.f.)	Within Fields (d.f.)
2·3	8	0·35 (7)	0·43 (18)
6·3	4	0·19 (3)	1·75 (13)
19·3	4	2·51 (3)	1·00 (5)

It is evident that there were real differences in the way the cysts were distributed within the fields of each group. Patchiness was most marked in the group of fields with intermediate populations ; it tended to even out in the fields with the highest counts.

This survey was initiated by Mr. L. N. Staniland and carried out by the staff of the Entomology Department, N.A.A.S., Bristol.

REFERENCES

FENWICK, D. W. and FRANKLIN, M. T. (1942). Identification of *Heterodera* Species by Larval Length. Technique for Estimating the Constants Determining Length Variations within a Given Species. *J. Helminth.*, **20**, 67–114.

FENWICK, D. W. and FRANKLIN, M. T. (1951). Further Studies on the Identification of *Heterodera* Species by Larval Length. Estimation of the Length Parameter for Eight Species and Varieties. *J. Helminth.*, **25**, 57–76.

A COLORIMETRIC METHOD FOR MEASURING DOSAGE DISTRIBUTION IN POTATO SPRAYING

by P. HEBBLETHWAITE

National Institute of Agricultural Engineering, Silsoe, Beds

During tests of spraying machines, a need was felt for a method of estimation which would enable spray dosage (as distinct from pattern of distribution of droplets) to be measured on numerous samples of leaves in a relatively short time. Large, Beer and Patterson (1946), when investigating the retention of copper fungicides, made copper analyses on batches of fifty discs (each 17·5 mm diameter) cut from a similar number of leaflets with a cork borer. This method does not differentiate between the deposits on the upper and the lower leaf surfaces. In testing the performance of spraying machines, it is necessary to ascertain the dosage applied, not only to leaves on all parts of the plants but also to the upper and lower surfaces of the leaves.

In the present method, evolved during work on spraying with copper fungicides against Potato Blight, a small quantity of a stock solution of black dye (Nigrosine G.140) was added to the fluid in the spray tank, the quantity being calculated to give a final concentration of between ½ and 2 per cent Nigrosine (the higher concentration being used in low-volume application rates). The estimation of dosage was then made, not on the amount of copper, but on the amount of dye present on the leaves, so that this method is not dependent on the use of a copper spray. Samples of leaves were collected after the spray had dried, and estimations were then made colorimetrically using an absorptiometer (Unicam S.P.400). Each leaf sample (usually a disc 1 inch in diameter as described below) was washed by shaking it in a test tube with a known volume of water, and, as the dye was easily soluble, the solution was poured immediately into an absorptiometer cell and a reading taken (Plate III, 4). A calibration curve was prepared for each batch of spray fluid by drawing a sample from the spray tank and preparing from this a series of known dilutions. In some cases, owing to the presence of dust, a small reading was obtained from washing unsprayed leaves ; this was applied as a correction to the readings from sprayed leaves, and in all estimations the quantity of dye and the volume of washing water used were adjusted to give dilutions in the part of the calibration range giving greatest sensitivity.

LEAF SAMPLING

Sample leaves were taken from three levels in the crop (representing the upper, middle and lower thirds of the foliage respectively) and from two zones (representing the inner and outer part of the foliage at each level). This enabled the dosage on the outer leaves, which were most exposed to the spray, to be compared with that in an inner core, which tended to be shielded from the spray by the outer leaves.

The dosage estimates were made on leaflets taken from whole-leaf samples, and to maintain the randomness of the sampling the leaflets on each whole leaf were regarded as though they were numbered in a clockwise direction starting with the apical leaf as number one, thus permitting the use of random numbers to govern the choice of leaflet.

To obtain independent estimates of the dosages on the upper and lower leaf surfaces, half the leaves from each of the regions of the plants were painted with a quick-drying rubber solution on the upper surface, and the other half of

the leaves were similarly painted on their lower surfaces. The solution was made by diluting "Cow Gum" (manufactured by P. B. Cow and Co. Ltd.) with petroleum ether until it could be applied with a soft ½-inch paint brush. The treated leaves could be handled in a matter of one or two minutes after painting.

Where the mean dosage over the whole surface of the leaflet was required, the whole leaflet was put in a test tube and washed as previously described. To obtain the mean dosage per unit area it was then necessary to measure the area of the leaflet with a planimeter, or to carry out a dry weight estimation of leaf area by some such method as that of Lemierre (1951). For many purposes, however, it is sufficient to cut a 1-inch disc from the centre part of the leaflet and to wash only this disc. This procedure is much simpler, and it may serve for comparing the distribution of dosage in different regions of the plants given by different machines, or by different arrangements of nozzles and lances. It has to be remembered, however, that the dosage on the centre part of the leaflets may vary from that on the leaflet as a whole. Large *et al.* (*loc. cit.*) illustrated the large amount of spray sometimes accumulated at the leaf tips by drainage or run-off.

EXAMPLE OF METHOD

The table below gives the individual measurements and means obtained on one of the batches of 1-inch diameter sample discs in a trial carried out on Majestic in 1954. In this case the plants, on August 16, were standing 20–25 inches high above the tops of the ridges, and were meeting across the drills but not sprawling. A tractor-mounted sprayer was used, and the Nigrosine was added to the copper spray used for blight control. There were three No. 4 swirl-type nozzles per row. One on the sprayer boom about 24 inches above the tops of the ridges was directed downwards and backwards (at an angle of 45 degrees) on the centre line of the row. The other nozzles were on the two drop-legs, on either side of the row and about 5 inches above the top of the ridge. These were directed upwards at an angle of about 30 degrees into the middle and lower levels of the foliage. The rate of application was 88 gallons per acre, at a pressure of 80 lb per sq. in., with tractor speed about 2 m.p.h.

VOLUME OF SPRAY FLUID RETAINED ON LEAF SURFACES
(Microlitres per sq. cm)

Upper Level of Plant				Middle Level of Plant				Lower Level of Plant			
Inner Zone		*Outer Zone*		*Inner Zone*		*Outer Zone*		*Inner Zone*		*Outer Zone*	
T*	B†	T	B	T	B	T	B	T	B	T	B
1·0	0·8	2·1	5·0	0·8	0·1	1·2	1·6	0	0	0·4	0·1
6·5	0·2	2·4	0·8	0·5	0·2	1·6	0·2	0	0	0·2	0·1
4·9	0·4	3·3	0·8	1·6	0	2·2	0·3	0	0	0·5	0
0·9	0·6	0·4	0·7	0·8	0·1	5·1	1·0	0	0	0·1	0
5·1	0·3	2·2	1·2	0·4	0·2	1·6	0·4	0	0	0·9	0·6
1·1	0·6	0·8	0	1·5	0	1·0	0·3	0·1	0·2	0·6	0·5
0·8	0·2	1·0	0·5	0·7	0·1	0·4	0·1	1·5	0	1·1	0·1
1·1	1·6	4·9	2·3	4·4	0·4	1·2	0·1	0·2	0·1	0·5	0·1
2·5	1·4	4·1	0	1·0	0	0·8	0·2	0·4	0	0·4	0·3
1·3	3·3	2·2	2·4	0·6	0·4	3·3	0	0·3	0	0·1	0
2·5	0·9	2·3	1·4	1·2	0·2	1·8	0·4	0·2	0	0·5	0·2

Means for levels:		Means for zones:		Means for leaf-surfaces:	
Upper	.. 1·8	Outer	.. 1·1	Top	.. 1·4
Middle	.. 0·9	Inner	.. 0·8	Bottom	.. 0·5
Lower	.. 0·2				

* T = Top (upper) surface of leaf

† B = Bottom (lower) surface of leaf

The results show the great variation from leaf to leaf to be expected in practical spraying, and the need for replicated sampling. In this particular trial six sets of figures—such as those shown in the table—were obtained for six sampling sites randomly spaced along a diagonal of the field, so that, in all, absorptiometer readings were made on 720 leaf discs. Statistical examination of the results showed that the differences between means for the three levels in the plants, and for the upper and lower leaf surfaces, were significant at the 1 per cent probability level, while those for the inner and outer zones of the foliage were significant at the 5 per cent level. The distribution of the data showed a definite positive skew, the standard deviation being to some extent dependent on the magnitude of the mean. For this reason the analysis of variance was carried out after log $(1 + x)$ transformation. In this trial, as the figures in the table indicate, the nozzles on drop-legs were achieving a considerable measure of cover on the under surfaces of the leaves, and penetration of the foliage appeared to be satisfactory, but the distribution as between the different levels of the plants was not satisfactory.

It must again be stressed that this method of estimation provides no information on the micro-distribution of the spray deposits on the leaves. This may influence the success of a spray application, and to reveal the pattern of the spray deposits, a leaf-printing technique using rubeanic acid (Large and Taylor, 1953) was used to supplement the Nigrosine method.

REFERENCES

LARGE, E. C., BEER, W. J. and PATTERSON, J. B. E. (1946). Field Trials of Copper Fungicides for the Control of Potato Blight. II. Spray Retention. *Ann. appl. Biol.*, **33**, 54–63.

LARGE, E. C. and TAYLOR, G. G. (1953). The Distribution of Spray Deposits in Low-volume Potato Spraying. *Plant Pathology*, **2**, 93–8.

LEMIERRE, A. (1951). Experimentation sur l'efficacité des Methods de Traitment Anticryptogamique. *Congrès International de Génie Rural, Rome*, 1951, 633–53.

OBSERVATIONS ON A RACE OF STEM EELWORM ATTACKING LUCERNE

by E. B. BROWN

National Agricultural Advisory Service, Cambridge

AND J. B. GOODEY

Rothamsted Experimental Station, Harpenden, Herts

Damage to lucerne by Stem eelworm, *Ditylenchus dipsaci* (Kühn), is well known overseas but was not recorded in Great Britain until 1948 (Brown 1953). Work in other countries suggests that the race is rather specialized. Frederiksen (1950) reports that in Denmark this eelworm attacks lucerne and *Melilotus alba* but no other tested leguminous crop, and López Cristóbal (1946) records that in the Argentine both lucerne and oats are attacked.

Stem Eelworm in Lucerne

A field upon which lucerne had been severely damaged in 1952 was chosen to investigate the host range of the eelworm in Great Britain. Self-sown plants of broad red clover, wild white clover and sainfoin were present among the infested lucerne but all appeared to be healthy. In 1953, four replicated blocks of plots, each plot consisting of two rows four yards long, were sown with the following plants : broad red clover, late-flowering red clover (English and Swedish strains), white clover (Kentish wild white and New Zealand certified mother seed), kidney vetch (*Anthyllis vulneraria*), yellow trefoil (*Medicago lupulina*), sainfoin, crimson clover, alsike clover, yellow suckling clover (*Trifolium dubium*), vetch (*Vicia sativa*), oats (S.147), maple pea (*Pisum arvense*), field bean (*Vicia faba*), potato, mangold and sugar beet. A row of lucerne was drilled between each plot, one row each of the three varieties Synthetic "A", Du Puits and Grimm being sown in succession. In addition, six rows of Synthetic "A" and one of Nemastan were drilled at the end of the plots.

The plots were examined in August and the only plants found to have been attacked were lucerne and alsike clover, with very slight damage to sainfoin. Most of the oats had been taken by birds within a few days of drilling, but no symptoms were found on a number of self-sown oat plants in the plot area. The rest of the field was down to Sun II oats and these were not attacked. Of the lucerne varieties, Grimm and Du Puits were showing signs of damage, whilst Synthetic "A" and Nemastan, both of which were bred in America for resistance to Stem eelworm, remained free from attack.

The farmer kindly allowed us to leave the plots down for a second year for further observations on the lucerne, alsike clover and sainfoin. No damage was seen on the sainfoin plants but the alsike clover was severely damaged. The lucerne varieties, Synthetic "A" and Nemastan, started growing very late in the spring and did not thrive. Three adult eelworms were found in one shoot of Synthetic "A" but they did not appear to be reproducing, and no eelworms at all were found in the Nemastan. The Grimm plots were severely damaged by eelworm and by the end of August had almost disappeared. The Du Puits plots remained remarkably free from damage throughout the season and, although attacked plants could be found, the stand was very good. Bingefors has reported (*in lit.*) that Du Puits is a fairly resistant variety in Sweden.

In Great Britain, therefore, lucerne and alsike clover may be considered hosts of this race of *D. dipsaci*. The variety Grimm is very susceptible and Du Puits appears to be fairly resistant. The American varieties Synthetic "A" and Nemastan, which were not bred for British conditions, were resistant to attack but did not thrive.

It is worthy of note that the lucerne race in Great Britain and in most other countries appears to be specific to lucerne and possibly other legumes, whereas that in Argentina attacks both lucerne and oats.

We are grateful to the National Institute of Agricultural Botany for supplying us with the seed of Nemastan and Synthetic "A".

References

Brown, E. B. (1953). Stem Eelworm in Lucerne. *Plant Pathology*, **2**, 54.

Frederiksen, H. (1950). Undersøgelser og Forsøg over Kløveraalens Udbredelse Skadevirkning, Smitteforhold og Bekaempelse. *Beretn. Planteavl. Sjaelland*, 1949, 245–79. (See *Helminth. Abstr.*, **19**, 287a.)

López Cristóbal, U. (1946). La Anguilulosis de la Alfalfa en la República Argentina. *Publ. Inst. Sanid. veg. B. Aires*, (*Ser. A*), **2** (20). (See *Helminth. Abstr.*, **15**, 236.)

SURVIVAL OF *PHYTOPHTHORA INFESTANS* IN POTATO STEM LESIONS

by ANGELA M. CLAYSON AND N. F. ROBERTSON

Botany School, Cambridge

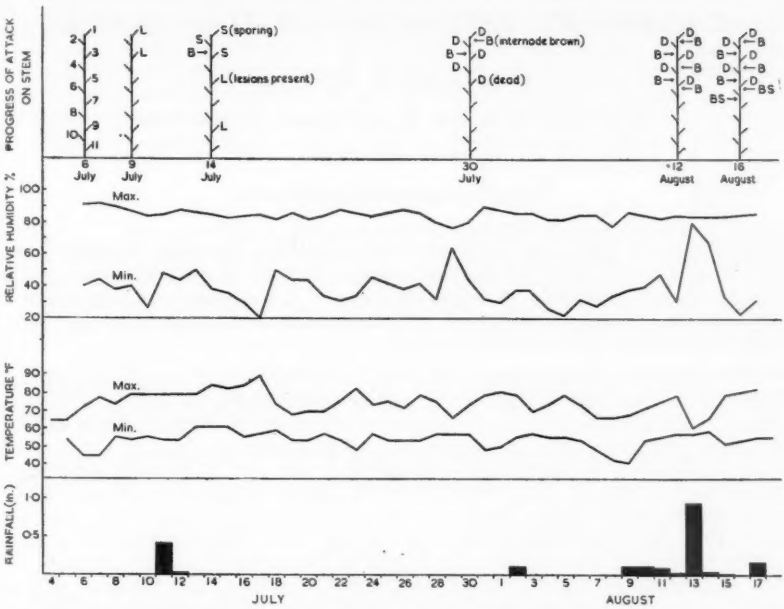
In the course of an experiment on inoculation techniques in 1955, some observations were made on the progress of blight in individual plants in the field. These observations were limited in scope, but it happened that they were made over an exceptional spell of hot, dry weather, unfavourable for the epidemic spread of the disease, and they provided a clear demonstration that, under such conditions, *Phytophthora infestans* can survive for extended periods in stem lesions.

Potatoes of the variety King Edward, planted in the third week of April 1955 at the Botany School Field Station, Cambridge, were inoculated with a zoospore suspension of *P. infestans* race 1,4 on July 4. At this time the plants had reached full height and were showing young flower trusses. Ten plants were sprayed with the zoospore suspension and, in order to follow in detail the development of the individual lesions, one shoot was chosen on each plant and marked by removing the tip to the first fully expanded leaf. The remaining stem internodes were then numbered downwards from the top for purposes of reference.

The inoculations were performed at 4 p.m., and the plants were then immediately covered with glass-topped metal incubation chambers. These chambers were removed from two plants, chosen at random, at 9.30 a.m., on each of the three succeeding days ; the remaining four plants being uncovered after seven days—that is, on July 11. Lesions began to appear on July 9 and, following rain on July 11, sporangiophores were observed on July 12. The plants first uncovered showed the largest number of sporing lesions, and only one of the plants that had been covered for seven days showed a few sporing lesions. With the onset of dry, hot weather all sporangiophores had disappeared by July 15. By this date there were stem lesions on the first or second internodes of the marked stems of three of the plants.

During the following thirty-one days, the stem lesions were observed to progress slowly downwards where the first internode was originally affected, and both upwards and downwards where the lesion first occurred on the second internode. In a fourth plant, uncovered on July 7, infection was seen to spread from the petiole of the fourth leaf into the fourth internode and thence upwards to involve internodes two and three. During this time no sporangiophores were observed but, following rain from August 9 to 14, sporangiophores were produced on three of the plants with stem lesions. On the fourth plant, which had the greatest number of leaves with lesions, stem infection had become so extensive that the whole stem was killed down to ground level. The history of one infected plant is shown diagrammatically in the figure below, together with relevant meteorological data.

The interest of these observations lies in the continuance of viable mycelium of *P. infestans* in the stems for a period of more than 40 days of hot, dry summer weather. It is common knowledge that blight epidemics are capable of revival after a period of dry weather, but there is little precise information on the survival of the fungus during the period of quiescence. Melhus (1915) infected stems in a greenhouse and observed the rate of spread of the lesions. He did



Progress of Potato Blight attack on stem of King Edward following inoculation on July 4, in relation to daily maximum and minimum relative humidity (in crop), daily maximum and minimum air temperature (in screen), and rainfall. Cambridge, 1954.

not keep the infected plants for longer than 5 days and does not specify the conditions in the greenhouse. Crosier and Reddick (1935) made observations similar to our own, but with potato plants in an unshaded greenhouse, and found that a small number of lesions on the larger stems contained viable mycelium after 30 days. Our experience suggests the need for further observations on this phase of the disease, with the common races of Potato Blight, and on a number of varieties.

We are grateful to the Agricultural Research Council for financial assistance during the course of this work.

REFERENCES

CROSIER, W. and REDDICK, D. (1935). Some Ecological Relations of the Potato and its Chief Fungous Parasite *Phytophthora infestans*. *Amer. Potato J.*, **12**, 205–19.

MELHUS, I. E. (1915). Hibernation of *Phytophthora infestans* in the Irish Potato. *J. agric. Res.*, **5**, 71–100.

A NEW BACTERIAL DISEASE OF DAHLIAS CAUSED BY *PSEUDOMONAS MARGINALIS*

by MARJORIE R. M. CLARK

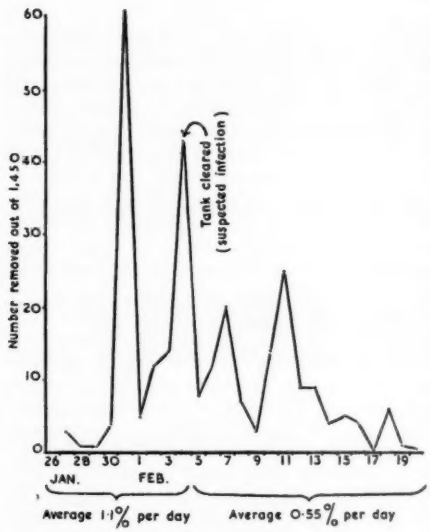
West of Scotland Agricultural College, Auchincruive

AND A. M. PATON

School of Agriculture, Edinburgh

During the last two years a new disorder of dahlias has been reported from several areas in the west of Scotland, and is thought to be fairly widespread among dahlias generally. It takes the form of a wet, black rot and is most troublesome on young cuttings in the propagation bed, although it has been seen from time to time on mature plants.

The character of the disease suggested a bacterial rot. Little mention is made in the literature of such conditions of dahlia and none in this particular setting. Chester (1938), however, described a stem rot of mature dahlias which, although presenting some interesting parallel features with those of the present study, differed in aetiology and was found to be due to *Erwinia cytolytica.* Attention had already been drawn by Wolf (1922) and others to the existence of a bacteriosis of dahlia associated with *Phytomonas solanacearum*, and by Hori (1911), who attributed a wilt disease of this host to *Bacillus dahliae*. Elliott (1930) considered this organism to belong to the genus *Erwinia.* In view of the occurrence of these different organisms associated with disease in the dahlia, it seemed desirable to elucidate the position with regard to the present disorder, and to investigate possible control measures.



Number of diseased cuttings removed each day during a peak period of infection.

Dahlia cuttings are normally taken from the stools in spring and raised under glass before being planted out in mid-May or early June. Growers with restricted accommodation who require to raise large numbers of saleable plants in time to meet orders, tend increasingly to root the cuttings early in the year, even in January. It is under these conditions that the disease causes the most serious losses. As many as 40 per cent of the cuttings have been attacked in individual batches, although the overall loss has rarely amounted to more than 10 per cent. The figure opposite shows the number of diseased cuttings removed each day over the peak period of infection in one outbreak.

Specimens of the infected cuttings first showed a flaccidity of the stem together with a slight shrivelling and drying of the base. Next, a wet, black rot became

apparent on the stem adjacent to this (Plate III, 2) and spread rapidly through the young shoot, usually within one or two days. On cuttings attacked later, another type of symptom appeared, this being an angular inter-veinal blackening of the leaf tissues (Plate III, 3), again spreading rapidly through the shoot. Affected mature plants presented a drier and paler appearance, and the infection was generally confined to one or two shoots (Plate III, 1).

NATURE OF THE DISEASE

The appearance of the tissues suggested a bacterial disease. A gram-negative rod-shaped bacterium was, moreover, present in profusion in sap expressed from the affected stem tissues of dahlias but was not readily found on the dry, blackened areas of the leaves. No other cause of the trouble emerged from a detailed examination. Watery suspensions of affected stem tissues were made and inoculated to dahlia tissues, by scratching stems, leaves and growing points of cuttings with a sterile needle through a drop of the inoculum. Small localized lesions resulted, which suggested that pathogenic organisms were present on the original diseased host.

Several pseudomonads were isolated by plating suspensions of diseased stem and leaf tissue on nutrient and meat infusion agar and by a special enrichment procedure (Paton, 1954). These isolates were used to inoculate dahlia tissues in the manner described above, and several of the cultures induced a wet, black rot, similar to that seen on the naturally infected cuttings. The rot was, however, rather more pronounced, being wetter and more generalized on all of these tissues. Controls, in which sterile water was used in place of the inoculum, remained healthy. A gram-negative rod-shaped bacterium was re-isolated from the blackened areas of the inoculated tissues, and later proved to be identical with the original isolates used for inoculation.

Some of the reactions took place with great rapidity, definite symptoms being seen on the young dahlia shoots in four hours, and the tissues being completely blackened and disorganized by the following day. Young, unrooted cuttings were found to be much more susceptible than mature plants or rooted cuttings on which the isolate produced only very localized lesions which did not develop further. Most of these pathogenic isolates were obtained from cuttings, but one came from a mature infected plant. As the season advanced and the days lengthened, it was found increasingly difficult to obtain the same clear-cut and rapid results of pathogenicity tests. The dahlia shoots used for inoculation purposes were now considered to have reached a stage of more vigorous growth before detachment from the stool and thus be less susceptible to attack as cuttings.

The isolates also produced a soft necrosis or grease-spot symptom upon lettuce tissue. Young bean tissues were also found to be susceptible to attack by at least one of the isolates, although a similar wet, black rot can apparently be produced in this host by other organisms.

IDENTITY OF THE CAUSAL ORGANISM

A bacteriological examination of the pathogenic isolates was carried out. All were identical and differed in a number of biochemical aspects from the other pseudomonads isolated. The symptom produced by these pathogenic isolates on lettuce tissues suggested the possibility of their being *Pseudomonas marginalis*. This view was supported by the biochemical characteristics of the

isolates which, on the whole, agreed well with those of *Ps. marginalis* (Brown) Stevens. One or two differences did, however, emerge, particularly with reference to the action on nitrate, but at present there appears to be no reason for distinguishing the organism from *Ps. marginalis*. Two biochemical characters of the isolates were outstanding and particularly useful in the identification of the pathogen—namely, the formation of easily identifiable mucoid-like colonies on 5 per cent sucrose agar and the production of gas in nitrate-peptone water.

Ps. marginalis has up to the present been recognized chiefly as the cause of a disease of lettuce (for example, Paine and Branfoot, 1924). As well as upon dahlias, we have found it on chrysanthemum cuttings, where it caused a very similar stem rot. It has probably a very wide host list under adverse conditions. Brown and Jamieson (1913) apparently isolated strains of a similar organism from sugar beet and nasturtium, as well as from lettuce. There is some doubt in the literature as to whether these were indeed strains of *Ps. marginalis*. Dowson (1949), however, considered that they were apparently identical with *Ps. aeruginosa*, *Ps. marginalis* being a non-pyocyanin-producing strain. Friedman (1951), found a soft rot of Witloof chicory to be due to *Ps. marginalis*, and successfully inoculated it to lettuce, escarole, endive, cucumber, onion, potato, carrot, string bean and broad bean.

DISTRIBUTION OF THE ORGANISM AND SOURCE OF INFECTION

The characteristic mucoid-like colonies and the production of gas in nitrate-peptone water shown by the organism, and referred to above, made it relatively simple to obtain information concerning the ecological distribution of the pathogen in a particular setting. One of the nurseries in which an outbreak was studied provided such a setting, since none of the other pseudomonads isolated from material at this site showed these characters together.

Numbers of *Ps. marginalis* were found on random specimens of unaffected parent stock cuttings, greenhouse soil (with and without the presence of cuttings), and dormant tubers. Except in the case of unrooted cuttings, it appeared that large numbers of the organism could be present on the various tissues without disease being evident. In the light of this and the pathogenicity tests described above, the unrooted cuttings must therefore be regarded as being particularly susceptible to the disease.

The widespread nature of the potential infection suggested that the source might be the greenhouse water tank. On examination, the water was found to contain large numbers of the pathogenic organism, in addition to a normal bacterial flora. Another possible source of infection was contamination from boxes of dahlia stools above the propagation bed, since drainage from these dripped on the cuttings below. The removal of these sources coincided with a lessening in severity of attack (*see* figure), and in the second instance more light was also admitted to the bed. It was considered that insufficient light might be another factor in promoting the disease, as the house was so situated that it could not receive full sunlight for the whole of the day. In both the main outbreaks studied, it was found that the disease became much less severe as day-length increased and stronger growth was obtained. In this connection, it will be remembered that a similar suggestion arose from the results of inoculation experiments in the laboratory. These facts indicate that a minimum daily period of light is important in avoiding outbreaks of the disease.

STUDIES ON CONTROL

The elimination of the source of infection in the water tank was the most obvious method of control. This was found to be more difficult than was anticipated, as the organism was still present even after treatment with disinfectant ; the slate-slab structure of the tank made it difficult, in practice, to obtain an effective degree of sterilization.

Ps. marginalis was found to be highly susceptible to streptomycin in the laboratory ; hence it was decided to use this antibiotic in an attempt to control the disease under field conditions. Various treatments with solutions of streptomycin containing a spreader were used either as a spray after planting (1,000 international units per ml) or as a one-hour dip before planting (220 international units per ml). The degree of control obtained (36 per cent) was not so great as desired ; one reason for this may be that streptomycin is known to decompose rapidly in soil. The decomposition of the antibiotic when used as a spray on the plants is not yet known, but it may also account for its relatively poor performance. The use of streptomycin in more direct contact with the plant is being investigated further.

We are indebted to Dr. T. Gibson and Dr. J. Grainger for their assistance. The co-operation of Mr. J. Crosbie of Ayr is gratefully acknowledged.

References

Brown, Nellie A. and Jamieson, Clara O. (1913). A Bacterium causing a Disease of Sugar-beet and Nasturtium Leaves. *J. agric. Res.*, **1**, 189–210.

Chester, F. D. (1938). A Bacterium of Dahlia, *Erwinia cytolytica*. *Phytopathology*, **28**, 427–32.

Dowson, W. J. (1949). *Manual of Bacterial Plant Diseases*. A. and C. Black, London.

Elliott, Charlotte (1930). *Manual of Bacterial Plant Pathogens*. Williams and Wilkins, Baltimore.

Friedman, B. A. (1951). *Pseudomonas marginalis* as the cause of Soft Rot of Imported Witloof Chicory. *Phytopathology*, **41**, 880–7.

Hori, S. (1911). (A Study of a Wilt Disease of Dahlia.) *Bull. Min. Agric. and Com. Nishigahara [Tokyo] agric. Exp. Sta.*, No. 38. 45–67.

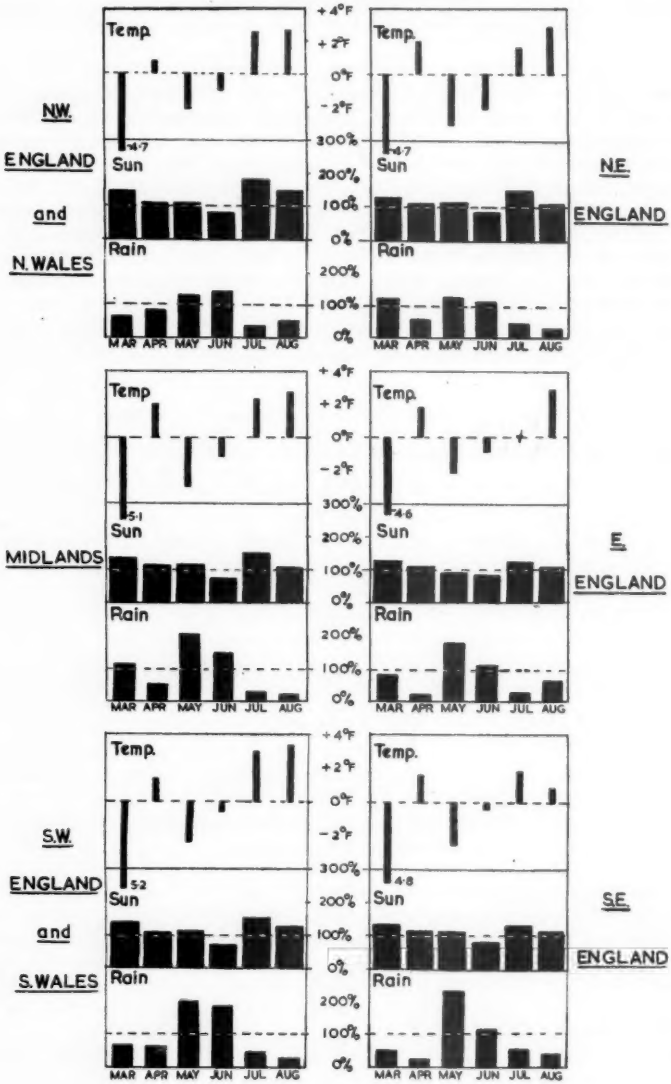
Paine, S. G. and Branfoot, J. M. (1924). Studies in Bacteriosis. XI. A Bacterial Disease of Lettuce. *Ann. appl. Biol.*, **11**, 312–7.

Paton, A. M. (1954). The Isolation and Identification of Species of Pseudomonas associated with Plant Diseases. *J. appl. Bact.*, **17**, XV–XVI.

Wolf, F. A. (1922). Additional Hosts for *Bacterium solanacearum*. *Phytopathology*, **12**, 98–9.

MARCH-AUGUST WEATHER 1955

Variations from average



THE WEATHER OF ENGLAND AND WALES*

SPRING AND SUMMER, 1955

The cold weather of the late winter persisted in all areas during March, except for a short, mild spell from 23rd to 26th. This mild spell was also rainy, and serious floods occurred in the Midlands. Otherwise the month was fairly dry and sunny. During April the temperatures recovered and were above average in all districts, reaching over 70°F in south-east England on the 29th. Much of the month was dry, especially in the east and south-east. The drought broke at the end of the month and May was cold and wet throughout. However, no very low air temperatures were recorded, although snow was experienced in southern England as late as on the 17th.

The cool, wet weather continued into the first summer month, although not in such an extreme fashion as in May. Night temperatures remained low, Kew recording its lowest June temperature for 32 years. With the coming of July the weather improved ; there was a long spell of easterly weather which gave warm, sunny days everywhere, except on the east coast, where cloud and sea fog persisted. There were scattered thunderstorms during the month but otherwise little rain fell. This traditional summer weather continued during the warmest August since 1947, all areas (including the east coast) having temperatures well above average.

The weather for each of the six months from March to August (inclusive) is represented graphically on page 36. Figures for the six districts of England and Wales are shown in terms of the deviation from the average of air temperature, sunshine and rainfall. These diagrams clearly show the predominating features of the period ; the coldness of March and May, the warmth of July and August, and the general dryness, apart from May and June.

NEW OR UNCOMMON PLANT DISEASES

***Mycosphaerella fragariae* on Strawberry Fruits.** In July 1955, I received from Clevedon, Somerset, some strawberries rendered unmarketable because of lesions on the berries. A number of the achenes present on the affected fruits were brown and some were surrounded by brown or straw-coloured, shrivelled depressions several millimetres in diameter (*see* Plate II, 1). Conidia of *Mycosphaerella fragariae* (Tul.) Lindau were present on many of the lesions. The typical symptoms usually produced by the fungus were present on the leaves, fruit stalks and sepals of plants bearing affected berries. Similar fruit symptoms, referred to as Black Seed, have been recorded from America (Demaree, J. B. and Wilcox, M. S., *Phytopathology*, 1938, **28**, 6).

L. OGILVIE

* These notes, and the diagram on page 36, are provided by the Agricultural Branch of the Meteorological Office and published by permission of the Director.

BLACK RUST ON WHEAT IN ENGLAND AND WALES IN 1955

It is unusual for Black Rust (*Puccinia graminis* Pers.) to become widespread or to cause appreciable damage on wheat in this country : indeed, in many seasons it is not reported at all. Occasionally, however, epidemics occur and in the ten years to 1954 there have been three (1947, 1950, 1952) in which the disease has been serious, although even then only in some south-western districts. 1955 was a similar year.

The first records of infection were made during the first week in July, when a conspicuous attack was seen on spring varieties, at flowering stage, on a trial in south Devon. Several varieties were also found to be affected on a trial in Somerset. By the end of July the disease was widespread in the South-West and in South Wales, and a few fairly severe attacks had been seen in south-west Hampshire and in Herefordshire. At harvest, many if not most crops in Cornwall, Devon, Dorset, south Somerset and south Wiltshire were affected seriously enough to lead to losses in yield. In adjacent districts to the east and north, including parts of Hampshire, most of Wiltshire, Somerset north of the Mendips, South Wales and coastal counties of mid-Wales (Pembrokeshire, Cardiganshire and Carmarthenshire), the disease had become widespread but appeared to have developed too late to cause any significant damage. A few isolated and sometimes quite severe attacks were reported from the West Midlands, the east and south-east (Kent and Sussex). There were no reports from areas north of a line from the Wash to the Wirral.

In general, spring-sown varieties were more severely affected than winter-sown. Records from a number of variety trials of both spring and winter varieties indicated that few showed any appreciable resistance. Among the spring varieties, Koga II, Alex and Peko were frequently badly attacked, while Atson and Atle (there were some conflicting reports on the reaction of this variety) were usually less affected. Severe infection was recorded on many winter varieties, including Squarehead's Master, Bersée, Cappelle Desprez, Heine VII, Hybrid 46 and Banco.

Accurate data on the effect of infection on yield are not available, but there were numerous reports of badly shrivelled grain from the districts where the epidemic developed, and estimated reductions in yield of 50–75 per cent of the expected crop were commonly quoted. In Devon, reductions of 2–10 cwt an acre were frequently claimed, and in south-west Somerset the average yield was about 15 cwt, instead of the usual 22–23 cwt. On at least two farms crops of Atle gave normal yields, while other varieties in neighbouring fields gave very much less. Much of the straw was useless for thatching.

There were only a very few reports of *Puccinia graminis* on barley and oats, and these were nearly all from the South-West.

Plant Disease Survey

(3914) Wt. 45 K.9 3/56 Hw

D

ad or
asons
n the
sease
ricts.

when
trial
al in
West
-west
os in
ected
and
f the
hire,
but
few
West
ports

nter-
inter
the
while
this
many
leine

here
the
f the
t an
was
os of
very

oats,

rvey